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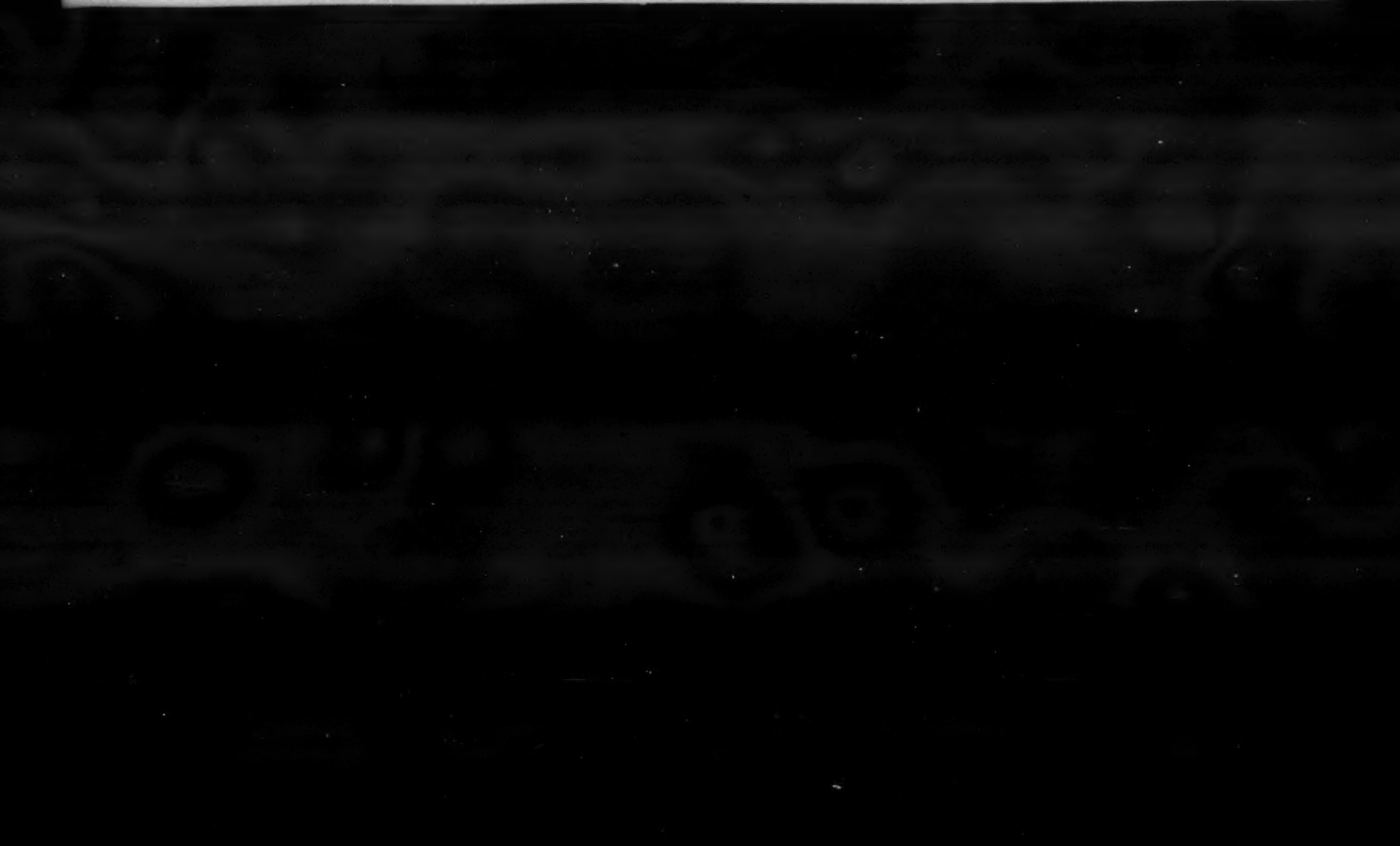


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVII.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN. With Plate V.

PART I. CARNIVORA.

INTRODUCTION.

IN pursuance of an understanding had with the late Professor Marsh shortly before his death, the writer has recently undertaken the study of the more important materials in the splendid collection of Eocene Mammalia in the Marsh Collection of the Peabody Museum, with the object of presenting a full account of the structure and relationship of those forms, as far as revealed by the remains at present known. This material was derived almost exclusively from the Bridger and Uinta Basins of Wyoming and Utah, but less extensive collections from the Eocene Basin of the San Juan of New Mexico are also included. The first collections of fossils from these localities were gathered in 1870, by the Yale Expedition into the Western Bad Lands, under the enthusiastic leadership of Professor Marsh himself. For four succeeding years, expeditions of a similar character were organized, equipped, and led into the fossil-bearing horizons of the West by this indefatigable student of paleontology, to whom the science is so deeply indebted. Later, for a number of years, Professor Marsh employed regularly trained collectors to search for fossils in the Bad Lands of these basins. The collections resulting from these sources have a richness and significance, perhaps unrivaled by any similar one in the world. The importance of the subject to the student of Mammalogy can scarcely be over-estimated, since these epochs witnessed the beginnings and branching off of many groups destined to play such a prominent part in

succeeding mammalian development. This fact was fully appreciated by Professor Marsh, and he spared neither pains nor expense in making the collections as complete as possible.

In 1871, he issued his first paper descriptive of these discoveries, in this Journal (vol. ii, August, 1871) and in succeeding years many publications in the same Journal were added. A few groups, Dinocerata, Coryphodontia, and Tillodontia, were described and illustrated *in extenso*, but by far the larger part of the collection has either not been studied or only a few specimens described in a brief preliminary way, mostly without illustration. For many years prior to his death, he had fully recognized the importance and desirability of having this subject, which the press of many matters had prevented his undertaking, finally and fully investigated for the sake of the advancement of the science. The Trustees of the Museum have, therefore, generously placed at my disposal this entire collection for study and publication, and it is to be earnestly hoped that the results obtained will prove commensurate with the importance of the undertaking. It is a source of the keenest regret to the author that the investigation could not have been made under the tutorship of the master whose ripe judgment and kindly advice would have proved so helpful and such a tower of strength in the preparation of the work. The subject will be considered group by group, omitting those that have been already fully published. The first of the series deals with the Carnivora, after which the Primates and other orders will follow. A consideration of the relationship of the horizons in which these fossils occur will be reserved for the latter part of the paper.

Part I. Carnivora.

In this group, I mean to include all those forms which are usually classified as the modern Carnivora, together with their extinct representatives commonly arranged under the ordinal group Creodonta. That all the modern Carnivores have arisen from and are directly traceable to what has been formerly known as the Creodonta is now coming to be so well established that from time to time it becomes necessary to modify our ideas of their classification and arrangement. According to the present state of evidence it seems probable that there were at least three if not more points of contact where the two groups actually unite. For this reason the distinction of one from the other becomes a more and more difficult task. I purpose, therefore, in the following treatise to consider the entire series as constituting a single homogeneous order, the origin of which dates back to Pretertiary times, along with the Edentates, Ungulates, and very probably, also, with the Insec-

tivores, Rodents, Primates, etc. There is as yet little or no evidence which throws any light upon their origin, and until the Cretaceous ancestors of the Monodelphs are more certainly known, the problem will of necessity remain obscure.

There appears to be a sort of vague belief that the Carnivora have arisen from the Insectivora, and one frequently hears the expression "Insectivore-creodont ancestors." Now, as a matter of fact, the Insectivora, as we at present know them, are not more primitive than a large majority of the Creodonts; but on the contrary, with very few exceptions, all the living Insectivores are considerably specialized, and even those that do exhibit a more or less generalized structure are far removed from the typical, ideal ancestor of the Carnivores. Nor do the few known fossil Insectivores help us much towards such a belief, for in all of them, as far as we know, the peculiar conformation of the anterior part of the skull is almost as strongly marked as it is in their living representatives. The very general enlargement of the premaxillæ and modification of the incisors, with the reduction or disappearance of the canine, constitute one of the striking osteological peculiarities by means of which they may nearly always be distinguished from any known Creodont or Carnassident.

It would appear from the present trend of the evidence that we shall be compelled eventually to return to the old idea of a direct Marsupial ancestry of all the Monodelphian orders. By this I do not mean to imply that the living Marsupials are these ancestors, for the reason that they have in all probability secondarily acquired a number of modernized features which remove them considerably from the hypothetical progenitors. Their peculiarities in the matter of the replacement of the teeth, the increased number of incisors in the carnivorous and insectivorous forms, and the inflection of the angle of the jaw, we may readily believe to have been acquired, and did not belong to their Mesozoic ancestors. In fact it has already been shown that the increased number of incisors is due to a development and partial retention of a first and second set.

Whatever may be said of the derivation of the other orders, the Mesozoic representatives of the carnivorous Marsupials are not far removed from the hypothetical forms, to which, it seems to me, the present evidence points with no doubtful signs, as the ancestors of the Carnivora. Although we know them from but a few fragments, yet the striking resemblances which these bear to the corresponding parts of the living carnivorous Marsupials, leave little doubt that their structure was very similar. If we subtract from the skeleton of some of the more typical living Marsupial Carnivores, such as the Sarcophiles, Dasyures, Thylacynes, and Opossums, those char-

acters which we may assume are specialized or secondarily acquired, we shall have left an assemblage of primitive features which must have certainly belonged to the ancestors of the Carnivores. These are especially seen in (1) the narrow more or less elongated type of skull, much constricted behind the orbits, (2) the stout, heavy zygomata, (3) the large lachrymal, spreading out upon the face, (4) the prominent sagittal crest terminating in a rather high, overhanging occiput, (5) the relatively large, downwardly projecting paroccipitals, (6) the double condyloid foramen, (7) the peculiar thickening of the posterior border of the palate, (8) the large hatchet-shaped neural spine of the axis, (9) the large size of the lumbar vertebræ as compared with the dorsals, and their tendency in some forms (Opossums) to develop the double tongue and groove articulations, (10) the large deltoid crest and characteristically broad distal end of the humerus, (11) the fusion of the scaphoid and centrale (Opossums, *Myrmecobius*, and Dasyures), (12) the subequal size of ulna and radius, (13) the large size of the lesser trochanter of the femur, (14) the large size of the fibula and its extensive articulation with the proximal surface of the astragalus instead of upon its outside, and (15) the very primitive form of the astragalus. To these may also be added, (16) the small size of the brain, (17) the dorso-lumbar vertebræ formula of 19, and (18) the posterior spreading of the nasals so as to exclude contact between frontals and maxillary in front. With respect to the forms of the teeth, they are with few exceptions primitive.

Now nearly all the foregoing characters are actually possessed in varying degrees by some members of the Creodonta, as far, at least, as we know them; and if the replacement of the dentition were complete instead of partial, and the so-called first molar of the carnivorous Marsupials, which is undoubtedly homologous with a persistent last milk molar of the diphyodont dentition, were replaced by a permanent simpler successor, as is invariably the case where its succession is accomplished, the analogy would then be complete and there would be no difficulties whatever in deriving the Creodonts from this source. In like manner the origin of the Insectivora would be traceable to a form similar to *Myrmecobius*. That the inflection of the angle of the jaw and the partial repression of the second set of teeth were secondarily acquired, is rendered probable from the recent discovery of Matthew* in which it would appear likely that both these characters have been acquired by the Mesonychidæ, among the Creodonts. Just what the Cretaceous Marsupials, when more fully known, will show with respect to these characters cannot now be predicted;

* Bull. Amer. Mus. Nat. Hist., January, 1901.

but we do know that such a type as *Didelphops* Marsh, in its dentition and palate, resembles the living carnivorous Marsupials, and it is to some such type in particular that I would refer the origin of the Creodonta.

The classification herein adopted with respect to the major divisions of the Carnivora is essentially that of Flower and Lyddeker in their work upon the Mammalia, with the exception that I have substituted for their name "Carnivora Vera" the subordinal term Carnassidentia. We shall then have the three suborders,—Creodonta, Carnassidentia, and Pinnipedia, but the difficulties of determining the limits and framing exact and satisfactory definitions for these groups, especially the two former, are just as great when considered as suborders as they are considered as orders. Two main features of their organization have hitherto been used to separate the Creodonts from the higher Carnivora or Carnassidentia, viz: the union of certain elements of the carpus and the modification of particular teeth into a sectorial or carnassial dentition. The relative importance of these two sets of characters in constructing the primary divisions of our classification is of course a matter upon which different opinions are held. Speaking for myself, I am convinced that the tooth characters are of greater moment in making these primary divisions than the union or non-union of certain carpal elements, for the reason that the ununited carpals are undoubtedly expressive of a generalized condition, which applied to all phyletic lines of this series in the early stages of their existence, and cannot, therefore, give the faintest hint of the breaking up into subordinate series. It is, moreover, largely dependent upon time, since later than a given epoch these carpals are united and earlier than this they are free, in any group belonging to the order.

If, on the other hand, we base our primary divisions upon the modifications of the teeth, we have from almost the earliest deposits in which we have knowledge of the remains of this group, many of the various phyla more or less distinctly outlined. Thus, as early as the Torrejon, we find representatives of the Viverravidæ, which not only have the teeth constructed upon the same identical pattern as that of certain living Carnassidentia, but the number is exactly the same. In the succeeding Wasatch, representatives of the modern Canids and Felids appeared, while the various lines of the Creodonta may be said to have been fully established by this time.

The one distinguishing feature of the dentition of the Carnassidentia is found in the fact that the fourth superior premolar and the first inferior molar have been exclusively developed into carnassial teeth. Some of the living representatives, such as the Bears and Raccoons, have largely lost the

more typical structure of these teeth, but the evidence is very strong in favor of their derivation from ancestors in which the carnassials were well developed.* In the Creodonta, on the other hand, if carnassial teeth are developed they are not confined to the fourth superior premolar and the first inferior molar, but usually consist of a varying number of molars in each series. In some of the older types there are no carnassials developed, the molars being intermediate in structure; while in others they are of a pronounced tubercular form. The three suborders would then be divided and defined as follows:

Suborder Creodonta.

Carnassial teeth present or absent; when present, not consisting exclusively of fourth superior premolar and first inferior molar. Scaphoid, lunar, and centrale of the carpus very generally free. Ungual phalanges broad, depressed and fissured, or laterally compressed and pointed. The following families are included: Oxyclænidæ, Arctocyonidæ, Mesonychidæ, Oxyænidæ, and Hyænodontidæ.

Suborder Carnassidentia.

Carnassial teeth present and always consisting of the fourth superior premolar and first inferior molar. Scaphoid, lunar, and centrale of the carpus, very generally united. Ungual phalanges compressed and pointed.

The following families are included: Viverravidæ Viverridæ, Hyænidæ, Protelidæ, Palæonictidæ, Felidæ, Canidæ, Procyonidæ, Ursidæ, and Mustelidæ.

Suborder Pinnipedia.

Limbs modified for progression in the water; no carnassials; scaphoid, lunar, and centrale united. Ungual phalanges greatly modified by enormous development of subungual processes.

Families: Otariidæ, Trichechidæ, Phocidæ.

Suborder Carnassidentia.

Family Canidæ.

The study of the Eocene Canidæ is attended with no little difficulty, owing in large measure to the insufficient and fragmentary materials upon which the types of the respective genera have been based. While fortunately these are not

* Matthew has (loc. cit., p. 17) quite recently discussed the relationship of the Arctocyonidæ, a family of the Creodonta from the Torrejon and Wasatch of this country and Europe, to the modern Bears. Arguing from the structure of the feet and teeth, he believes that they make certain distinctive approaches towards the Ursidæ and may have been ancestral to them. Had he taken the trouble to compare the feet of *Clænodon* with a living Opossum or a Dasyure, he would have found such a striking similarity of structure in every detail, with the possible exception of the astragalus, that he would have concluded that the Arctocyonidæ are much nearer to the Marsupials in these characters than to the Bears.

numerous, yet with such imperfect specimens it is not an easy matter to correctly determine their limits and relationships nor to refer other more complete material to them with certainty and exactness. Any attempt must, therefore, be regarded as tentative to a large extent, at least until such time as the acquisition of more complete specimens will throw additional light upon the structure and organization of the types.

The genera which have been proposed for these dogs are three in number, viz: *Vulpavus*, proposed by Marsh in 1871 upon a first superior molar tooth; *Uintacyon*, proposed by Leidy in 1872 upon an anomalous lower jaw, with the teeth considerably damaged, and *Miacis*, proposed by Cope in 1872 upon a fragment of a lower jaw bearing the penultimate molar. It will be seen, therefore, that in no case is there association of upper and lower teeth in one specimen, so that in the absence of any additional specimens which display characters exactly like the types, the reference of other more or less fragmentary material to them must, at best, be attended with an element of uncertainty.

In the matter of the synonymy of these generic names I have elsewhere expressed the opinion* that the type specimen of Cope's *Miacis* belongs to the same genus as that previously described by Marsh under the name of *Vulpavus;* but in the absence of superior molars in the former, this cannot be demonstrated with absolute certainty. After the study of a much wider range of specimens than were at my disposal when this conclusion was reached, I can see no reason to question the correctness of this view.

Fortunately the relationship of the type species of *Uintacyon* can now be determined with a reasonable degree of certainty and satisfaction. In the present collection a specimen in which there are upper and lower molars associated, shows that it is quite distinct from *Vulpavus*. While the number of superior molars cannot now be stated, they may nevertheless be assumed to be three; this assumption is based upon (1) the relative size of the second molar, the presence of which is indicated by its alveolus, and (2) upon its striking resemblance to the three-molared Oligocene *Daphænus* series, of which there can be little doubt that it was the forerunner. The main distinction between *Vulpavus* and *Uintacyon* has hitherto been supposed to rest upon the number of superior molars. *Vulpavus* was thought to have but two and *Uintacyon* three, but it now transpires that some of the species of *Vulpavus* have a third molar, and it is no doubt true of all of them; in fact it seems highly improbable that there are any species of Canids in the Bridger which had less than three superior molars. The dis-

* Bull. Amer. Mus. Nat. History, June 21, 1899, p. 110.

tinctions between the two genera are seen in the following characters: in *Vulpavus* the jaw is relatively slender, the heel of the inferior sectorial is comparatively small and basin-shaped, the second and third lower molars have sharp cusps, the main internal cusp of the first superior molar is large, lunate, and connected with the outer cusps by an anterior and posterior ridge upon which intermediates are developed, and there is a postero-internal cusp. In *Uintacyon*, on the other hand, the jaw is thicker and more robust, the heel of the inferior sectorial is small and cutting, the cusps of the succeeding molars are low and obtuse, the main internal cusp of the first superior molar is more conic and connected with the external cusps by a ridge in front only, and there is no posterior internal cusp.

A third group having the jaw characters of *Uintacyon*, as far as known, is represented by a few scattering fragments. In this group the premolars are much reduced in size and the canine is laterally flattened. Members of this latter group are found in the Wind River and Wasatch deposits, which carries them well back towards the base of the Eocene. That they represent a distinct and independent phylum there can be little doubt, and one, moreover, that is known to have left descendants in the succeeding Uinta beds.

If, upon further investigation, it should be found that the scaphoid, lunar, and centrale of the carpus are separate, which is not altogether improbable, the question will then arise as to whether they should be properly classed in the Canidæ or Viverravidæ or whether they should be placed in a distinct family by themselves. According to the previous and perhaps more common acceptation of the limits of the Creodonta they would without doubt be placed in this suborder, but I believe with Schlösser that they stand much nearer to the Carnassidentia and, as I will presently attempt to show, were the immediate progenitors of the two and probably three main branches of the canine phylum. If we range them with *Viverravus* in the Viverravidæ we shall fail to express by such a classification the distinctive and important positions which these two genera hold with respect to the canine and viverrine branches of the Carnassidentia. There now appears to be little doubt that when the evidence is more complete than it is at present, it will be found that the Canidæ and Viverravidæ were derived from a common ancestor. That the separation of these two genera took place, however, previous to the deposition of the Torrejon beds is evidenced by the fact that a species of *Viverravus*, with all the distinctive dental characteristics of this genus, is found therein, and we must therefore look to an earlier date for the

actual convergence of the two groups. If the Viverravidæ were the forerunners of the civets, which appears from present evidence to be exceedingly probable, then the dogs and civets have had a common origin, as has been so frequently insisted upon by Scott.

Vulpavus Marsh.

Vulpes, a fox; and *avus*, a grandfather. Amer, Jour. Sci., 3d ser., vol. xi, p. 124, Aug., 1871. *Miacis* Cope (in part). Paleont., Bull., No. 3, Aug. 7, 1872, p. 2; Proc. Amer. Philos. Soc., p. 470, 1872: Tertiary Vertebrata, 1884, p. 301. *Vulpavus* Wortman and Matthew, Bull. Amer. Mus. Nat. Hist., June, 1899, p. 118.

A group of small dogs limited in their vertical distribution, so far as at present known, to the Bridger Horizon. They are characterized by having the dental formula I. $\frac{3}{3}$, C. $\frac{1}{1}$, Pm. $\frac{4}{4}$, M. $\frac{3}{3}$, with the relative proportions of the lower molars nearly the same as in the modern genus *Canis*. The antero-external angle of the first superior, and to a less degree that of the second superior molar, is drawn out, and produced into more or less of a cutting blade. The external cusps are unequal in size, the anterior being the larger. The hind foot is pentadactyle, the astragalus little grooved, and the femur has a third trochanter. The humerus has a powerful deltoid crest and supinator ridge, and there is a large entepicondylar foramen. The articulations of the lumbar vertebræ are not complex as in some Creodonts but plane as in most Carnivores. The claws are compressed, sharp pointed, and unfissured. The carpus is unknown.

Vulpavus palustris Marsh.

Professor Marsh, in describing the remains upon which this genus and species were primarily established, included a portion of a right superior maxillary, carrying the fourth premolar and the roots of the three succeeding molars. Since this specimen agrees so perfectly in every respect with a species of the genus *Sinopa* Leidy, and differs in such important characters from the accompanying molar, it may be confidently excluded from any further consideration in this connection. The type, figure 1, consists of a first superior molar tooth of the right side, with the antero-external angle missing; otherwise the crown of the tooth is in a perfect state of preservation. The specimen indicates an animal considerably smaller than the common Red Fox with which Professor Marsh compared it in his original description. The composition of the tooth crown, and the arrangement of the component cusps and ridges indubitably stamp it as belonging to a mem-

1

FIGURE 1.—*Vulpavus palustris* Marsh; first superior molar; crown view; natural size. (Type.)

ber of the Canidæ, and the name *Vulpavus* was most happily chosen, since it is not only the forerunner of the foxes in name but is so in fact.

Like most of the Canidæ the crown is composed of two principal external cusps, a large lunate internal ridge enclosing a central depression or valley, together with a more internal and posterior ledge-like elevation arising from the cingulum. The external portion of the crown is very different from the corresponding part of this tooth in any of the Miocene, Pliocene, or modern species of dogs, but resembles that of the great majority of the older and contemporary Creodonts. This consists in its external expansion, and the formation of a relatively broad shelf-like area between the external margin of the crown and the two external cusps. Associated with this is the drawing out of the external angles, both anterior and posterior in this species, and the disposition to form cutting blades of these parts of the crown. While the antero-external part of the tooth is broken away in the type specimen, there can be little doubt, from its great similarity in structure to the nearly related species described below, that this angle was present and prominent.

Of the two external cusps, the anterior is by far the larger and more prominent, and as this character appears to be constant in all the species thus far known, it may be taken as of generic significance. The crescentic ridge thickens considerably at its internal angle into a low, stout, more or less trihedral cusp which forms its most prominent part. External to this the ridge is interrupted by two, less prominent, anterior and posterior intermediate cusps situated about midway of the tooth crown on the respective borders which they occupy. The postero-internal cingular cusp is unusually broad and thick for such an early species of the Canidæ, in fact almost equaling in this respect some of the modern species. The summit of this cusp is closely connected with the cingulum which is developed around the entire crown.

The locality of this specimen, which is the only one in the collection, is Grizzly Buttes. This locates it near the base of the horizon; it was found by Professor Marsh.

The following measurements are given:

	mm.
Transverse diameter of posterior part of crown	8
Antero-posterior diameter in middle of crown	4·5

Vulpavus Hargeri sp. nov. (Plate V.)

Two specimens of this species, which include a considerable part of the skeleton, are contained in the collection. From these a fairly accurate knowledge of a large part of the

osteology may be obtained. In one, which is here selected as the type, figures 2 and 3, the larger portion of the anterior moiety of the skull, together with a few fragments of other bones of the skeleton, are preserved, while in the other, parts of the skull, vertebræ, one hind limb complete, parts of fore limb, ribs, etc., are present in more or less perfect condition. There is one other specimen in which there are upper and lower teeth in association, and in this specimen the alveolus for the third superior molar is clearly shown.

Skull and Dentition.—The facial portion of the skull is sufficiently preserved to admit of description; this together with some fragments of the base of the skull and the larger part of the cranial vault serve to give a reasonably accurate idea of the skull. As compared with the Red Fox, the muzzle is shorter and less slender, resembling in this respect the Miocene *Cynodictis gregarius*, with which it agrees fairly well in size. The orbit is relatively larger than in this latter species, holding about the same proportions as that seen in the fox. Its anterior edge lies over the anterior half of the sectorial as in *Cynodictis*, while in the fox the orbit is more posterior. The infra-orbital foramen is larger and occupies its usual position on the side of the face; its posterior edge is a little more posterior than in *Cynodictis*, coinciding with the anterior border of the superior sectorial as in the fox. The skull is much constricted behind the orbits as in *Cynodictis*, in marked contrast with the relatively broad area of this region in the fox. There is a distinct postorbital process present, although it is small as in *Cynodictis*. The lachrymal has the same relative size and proportions in the three genera and is not spread out on the face; there is a small lachrymal tubercle present, which is less conspicuous in *Cynodictis* and absent in the fox. The two converging branches from the postorbital process unite just in front of the postorbital constriction to form a sagittal crest of moderate proportions just as in the case of the Miocene *Cynodictis*. In a large majority if not all the foxes, as is well known, these branches do not unite until near the lambdoidal crest, leaving a large lyrate area in this region of the skull. The development of this lyrate area is no doubt due to a progressive widening of the anterior part of the brain. In all modern species the postorbital constriction is very much less than in either the Miocene or Eocene forms. The zygomatic arches are well developed and display a somewhat greater degree of stoutness than that of *Cynodictis* and the fox.

A portion of a left squamosal exhibiting the glenoid fossa is sufficiently preserved to indicate the existence of an unusually broad postglenoid process; this is divided by a deep notch

into an external and an internal portion of which the external is the larger. The office of this notch, which appears to be a part of a foramen, is not altogether clear, but it is a matter of much interest to note that a similar arrangement is seen in the skull of the carnivorous Marsupials. Placed internal to and close to the edge of the fossa is seen the opening of the foramen ovale, much closer in fact than in any species of dog with which I am acquainted. This condition would seem to indicate a narrow brain case, which would be in keeping with the position of the species in the time scale. The position of the foramen is posterior to the fossa as in the Marsupials, and not anterior or opposite to it as in *Cynodictis* and the modern dogs. Posterior to the glenoid is seen the opening of a rather large postglenoid foramen.

The lower jaw, figure 2, is relatively a little stouter than that of *Cynodictis* and considerably more so than that of the fox; its inferior contour is like that of the typical dogs, being deepest in the region of the inferior sectorial, tapering thence forwards, and more or less curved posteriorly. The symphysis is short, extending to beneath the anterior border of the premolar as in *Cynodictis*. In the fox the symphysis is larger and more extended, reaching backward to beneath the anterior border of the third premolar. The angle is broken away in all the specimens of this species in the collection, but the base indicates that it was present and of apparently the same proportions as in *Cynodictis*. There is an appearance of a slight degree of inflection having been present. The masseteric fossa is relatively large and deep, occupying quite one-third the entire length of the jaw; it has about the same proportions as in *Cynodictis* but is considerably smaller in the fox. The coronoid is much damaged, but there is evidence of its goodly proportions, both as regards breadth and height. The condyle is somewhat heavier and of greater transverse extent than in either the Miocene or recent genera.

With the exception of the last superior molar and the superior incisors, the dentition can be fully described. The canines are of moderate size, more or less oval in cross-section at the base, and well pointed. Of the inferior premolars the first is small, single-rooted, with a somewhat conical crown, and separated from the canine and second premolar by short diastemata. The second has a flattened pointed crown, is implanted by two roots, and separated from the tooth in advance by a diastema. The third and fourth are larger two-rooted teeth with laterally compressed conical crowns having distinct anterior and posterior basal cusps. The third has in addition to these a faintly marked accessory cusp developed upon the posterior border of the crown.

The first molar, or sectorial, bears the unmistakable stamp of an early or primitive condition of this tooth in the Carnassidentia. This is particularly noticeable in the great elevation of the trigon above the heel, in the large size of the internal cusp and the arrangement of the cusps of the trigon in the form of an isosceles triangle, in the obliquity of the principal shear to the axis of the jaw, and the development of a posterior shear. In the sectorial of *Cynodictis* or of a modern dog, the trigon is less elevated, the principal shear is more in

2

FIGURE 2.—Left lower jaw *Vulpavus Hargeri* Wortman; crown view; one and one-half natural size. (Type.)

line with the jaw axis, the internal cusp of the trigon is reduced, and the posterior shear has practically disappeared. Of the trigon the external or principal cusp is unusually high and prominent; it has a distinctly trihedral form, with the anterior cutting edge but little produced, in marked contrast with that of *Cynodictis* or the fox, in which the whole cusp is laterally flattened and the anterior edge drawn out into a cutting blade. The anterior cusp is prominent and relatively thick; its posterior edge is extended and forms the more important blade of the principal shear. The internal cusp is large and with the principal outer cusp forms a posterior, transverse shear of considerable efficiency, which bites against the anterior edge of the first superior molar. The heel or talon is proportionally small; it is made up of an inner basin-shaped and an outer vertically beveled part, divided from each other by an antero-posterior median ridge, which is terminated behind by a rounded cusp and continued forwards to the base of the trigon. The inner boundary of the basin is furnished by a ridge of moderate proportions which curves around posteriorly to join the median cusp, inclosing between it and the median ridge a concavity. The antero-posterior ridge joins the base of the trigon immediately posterior to and beneath the notch which separates the blades of the posterior or transverse shear. The extent to which this outer beveled portion of the heel is developed varies much in the different species of Canidæ; it has to do apparently with the pushing inwards of the principal external cusps of the first superior molar, for when they have

an internal position the beveled portion is large as in the present species, and when they have an external position the beveled portion is reduced and its position is taken by the basin-shaped part. Taking the present species as one extreme and the modern dogs as the other, the genus *Cynodictis* stands about midway between the two in this respect.

The second molar is a diminished copy of the sectorial with the exception that the trigon is much less in height, and there are less distinctive shears developed among the elements of the trigon. The cusps as well as the heel have approximately the same relations to each other. In *Cynodictis* and the modern dogs this tooth, as well as the succeeding one, has lost all traces of the sectorial structure. The third molar is still more reduced, being relatively as small as in the modern species; the crown, however, still retains traces of the tuberculo-sectorial pattern, although but faintly.

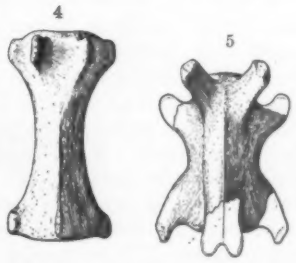
3

FIGURE 3.—Left upper jaw of *Vulpavus Hargeri* Wortman; crown view; one and one-half natural size. (Type.)

Of the superior dentition, figure 3, the canines are of moderate size and pointed, resembling those of the Miocene *Cynodictis*. The first premolar is a small single-rooted tooth placed close to the base of the canine; a short diastema intervenes between it and the second. The second and third are, as is usual among the Canidæ, two rooted, with laterally flattened, pointed crowns; the third has a posterior basal and accessory cusp like the corresponding tooth in *Cynodictis*. The superior sectorial displays the usual form seen in the Canidæ, although in some respects it is primitive. The two external cusps are large and modified into very efficient shearing blades. At the base of the large antero-external cusp is seen a small tubercle which recalls the structure of the superior sectorial among the carnivorous viverrines. In this latter group, however, it is larger and more distinct, while among the cats and hyænas it has been developed into a powerful third blade. The genus *Ælurodon*, a dog-like mammal from the Loup Fork Miocene of America, likewise exhibits this cusp but in a less degree of development. The internal cusp is unusually large and has an anterior position, displaying about the same proportions as are

observable in *Herpestes* or *Viverriculus*. It is much larger than in the corresponding tooth of either *Cynodictis* or the fox.

The molars display the same generalized characters as those of the type species *V. palustris* already described, and, notwithstanding some minor specific differences, they are undoubtedly indicative of the same genus. The anterior border of the crown of the first molar is relatively much elongated in a transverse direction. The two external cusps, of which the anterior is the larger, are placed well inwards, and a considerable ledge-like area which is broadest in front intervenes between them and the external border. The postero-external angle is more or less rounded, and is not produced into a sharp crest as in the type species *V. palustris*. The large internal cusp is not as lunate in character as in the type species but is more pointed and distinctly separated from the rather large anterior intermediate, the posterior intermediate being small. The postero-internal cusp, which is so highly characteristic of nearly all species of the Canidæ, may be said to be practically absent; a rather strong development of the cingulum marks its position, however, but even this is somewhat variable in the several specimens in which it is shown. The almost total absence of this cusp is in marked contrast with its strong development in the type species. The crown of the second molar is almost an exact copy of that of the first; it is, however, smaller and all the cusps are less distinct. The third molar is not preserved, but its presence is indicated by the alveoli in the two specimens in which it is shown. It was small and vestigial in character.



FIGURES 4, 5.—Caudal vertebræ of *Vulpavus Hargeri*; natural size. (Cotype.)

Vertebræ.—There are comparatively few of the cervical or dorso-lumbar series of vertebræ preserved, so that it is impossible to give an account of either their number or characters. Some fragments of the lumbars, in which the zygapophyses are fairly perfect, indicate that their centra were large as in the early Carnivora and that their articulations were not complex as in many Creodonts. Some well-preserved caudals, figures 4 and 5, show that the tail was large and presumably of good length.

Scapula and Fore Limb.—The head of the scapula presents the same pyriform, cup-shaped glenoid cavity as that seen in

the fox, but the coracoid is larger and more elongate as in *Cynodictis*. The neck is short, the spine rises abruptly, close to the glenoid border, and terminates in an overhanging acromion and metacromion. There is not enough of the bone preserved to indicate the relations of the fossæ with certainty, but they were apparently like those of *Cynodictis* as described by Scott.*

6

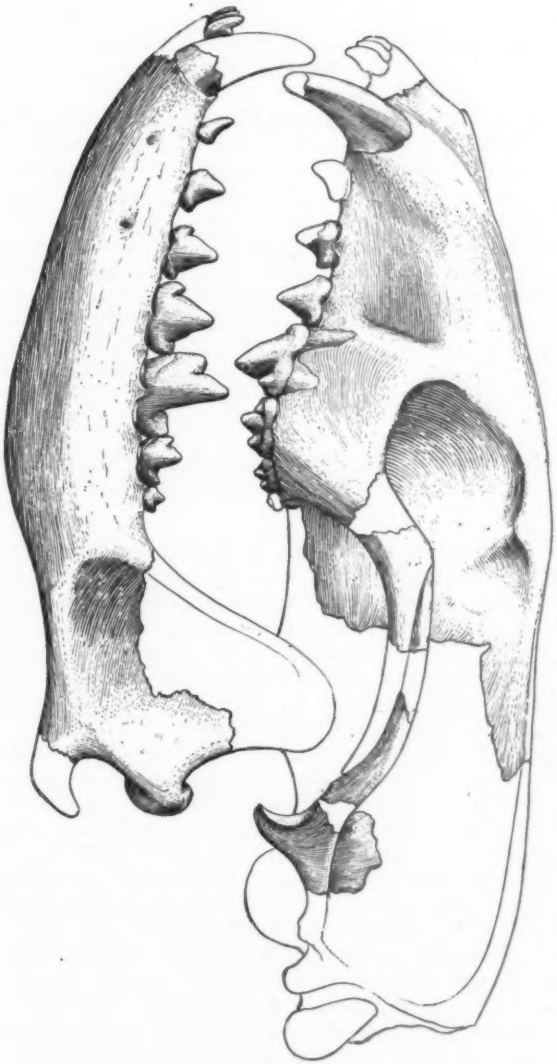
FIGURE 6. — Left radius of *V. Hargeri* Wortman; natural size.

The humerus, figure 9, is broken in the region of its proximal third and does not give the character of the head of the bone. The most conspicuous feature of the shaft is the development on its anterior surface of the very large and prominent deltoid crest, which extends more than half way to the distal end. Associated with this are seen the unusually prominent supinator ridge and internal condyle, all of which serve to give to the bone a combination of characters hitherto completely unknown among the Canidæ. The entepicondylar foramen is present but there is no anconeal perforation. The anconeal and anticubital fossæ are distinct and the articular surface is of unusual transverse extent, as it is in the cats and viverrines, and very different from the modern dogs.

The radius, figure 6, resembles that of the civets much more than of the modern dogs. The shaft is slightly curved and moderately flattened. The head is cup-shaped and subcircular in outline, indicating power of complete pronation and supination; the tubercle for the insertion of the biceps is strong and that for the principal pronator of the fore arm is unusually well developed. The distal end is broken so as to destroy a considerable part of the articular surface for the carpus. Judging from what is preserved of this surface, however, there was apparently no division into separate scaphoid and lunar facets. This would seem to indicate a consolidated scapho-lunar, but this evidence is not altogether reliable.

* Trans. Philos. Soc. Phila., vol. ix, p. 381, 1898.

[To be continued.]



EXPLANATION OF PLATE V.

Skull of *Vulpavus Hargeri* Wortman; side view; one and one-half natural size (Type).

Art. XXVIII.—*On the Velocity of Chemical Reactions;* by William Duane.

In investigating the laws of physical chemistry it is expedient for the physicist to devise and develop the methods of measurement, and for the chemist to apply them. In the following pages are described two methods of measuring the velocity of chemical reactions. The velocity of a chemical reaction is the rate at which a chemical compound appears or disappears during that reaction. The changes in the quantity of this compound present during successive intervals of time are measured by the changes in some property of the chemical system during the intervals. This property is usually either a chemical or a physical one.

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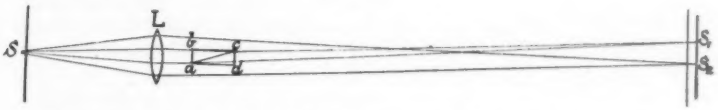

In the first of the following methods the basis of the measurement is the change in the index of refraction of the system, and in the second the change in its volume.

The first method is applicable to those chemical systems only that are transparent. It is substantially the following. Rays of light from an illuminated slit S (Fig. 1) passing through a long focus lens L and the tube *a b c d* form a distant image S_1 of S. The slit S is perpendicular to the plane of the diagram which represents a horizontal section of the apparatus. The tube *a b c d* has plane glass ends *a b* and *c d;* and a plane glass plate *a c* divides it into two wedge-shaped compartments. The ends *a b* and *c d* are not quite parallel to each other, so that if the two compartments are filled with liquids having the same index of refraction there will be a slight resultant refraction of the light rays that pass through the tube. The rays of light that pass outside of the tube therefore will form an image S_2 a little to one side of S_1. It is evident that if the liquid in one compartment (the wedge *a c d* for instance) is undergoing a chemical change its index of refraction in general will vary and the image S_1 will move sideways. The distance that S_1 has moved will be a measure of the change that has taken place in the index of refraction and, therefore, of the amount of substance in *a c d*, that has reacted. The displacements of S_1 can be determined by comparing its distances from S_2 which remains stationary.

In order to obtain a complete record of the position of S_1 a photographic plate S_1S_2 is placed in a vertical position at the images S_1 and S_2 and just in front of it a screen. A narrow horizontal slit cut in the screen allows a small part of the light only to pass through. At any instant of time, therefore, there will be two small spots of light on the plate at the intersections of the two images S_1 and S_2 with the projection of the slit on the plate. A system of cog-wheels allows the photographic plate to fall slowly during the reaction so that two lines are drawn on it, one of them straight due to the fixed image S_2 and the other curved due to the moving image S_1. The curved line represents the reaction in that the absyssas are proportional to the intervals of time and the ordinates represent (but are not proportional to) the quantities of the substance that have reacted. After the reaction is completed the plate is drawn up and lowered again and the image S_1 traces a third line that is practically straight. This line may be taken as the zero line and the distances between it and the curved one are (at least in some cases) proportional to the amounts of the original compounds left in the solution.

2

Fig. 2 is a reduced copy of a photograph representing the inversion of a 25 per cent solution of cane sugar, the inversion being accelerated by the addition of hydrochloric acid. The middle horizontal line represents the position of the image S_1 twenty-four hours after the reaction had started. The vertical lines were drawn with a dividing engine after the plate had been developed. The distance between two successive lines repre-

sents fifteen minutes. This distance was determined on a separate plate by lighting a magnesium burner for an instant every hour at some distance in front of the horizontal slit, and by measuring on the dividing engine the distance between the lines thus formed. A heavy vertical line to the extreme right of the plate (not seen in the copy) is a magnesium flash-light line and represents the instant at which the hydrochloric acid and sugar solution were mixed.

The photographic plate was fastened in a frame hung on a fine iron wire that was wrapped around a cylinder on the axle of one of the wheels in the works of a clock. The escapement of the clock was operated by an electro-magnet the circuit of which was made and broken by the swing of the pendulum of a standard clock. On account of the escapement the downward motion of the plate was by jerks, but as each jerk carried the plate only about $\frac{1}{20}$th of a mm. this is not apparent from the photograph.

It is evident from the way in which the fifteen-minute lines are drawn that no correction need be made for the shrinkage of the gelatine films, for practically the same shrinkage takes place on one plate as on another. The shrinkage too reduces all the ordinates of the curve in the same proportion, and if the relative positions of the images are always determined by measurements on a photographic plate no correction need be applied to the ordinates.

The object of having two wedge-shaped compartments is to reduce the dispersion of the light passing through them as much as possible, indeed white light from an incandescent lamp can be used. The solution in the wedge *a b d* is the same as that in *a c d* except that in it the reaction has already taken place. Under these circumstances the indices of refraction in the two wedges are very nearly equal and a slow change of a few degrees in temperature does not displace the image S_1 since such a change affects the index of refraction in both solutions practically to the same extent.

In the above described experiment the dimensions of the apparatus were as follows: SL (Fig. 1) = 150^{cm}; LS_2 = 250^{cm}; ab = 1^{cm}; ad = 5·3^{cm}; Lb = 15^{cm}, approximately. The breadth of the slit in front of the figure was ·2^{mm}, and its distance from the figure about ·3^{cm}.

That the distance of the image S_1 at any time from its final position after the reaction has been completed is very approximately proportional to the amount of cane sugar left in the solution at that time, may be seen from the following reasoning. The proof is based upon the assumptions that the density d and the specific index of refraction $\frac{n^2-1}{n^2+2} \cdot \frac{1}{d}$ of the solution

(where n is the ordinary index of refraction) are additive functions of the constituents (see Nernst, *Theoretische Chemie*). Granting these, it follows that the difference between the value of $\frac{n^2-1}{n^2+2}$ at any time and its final value must be proportional to the amount z of cane sugar remaining at that time. Denoting this difference by Δ we have

$$\Delta \frac{n^2-1}{n^2+2} = k z$$

Approximately for small changes

$$\Delta \frac{n^2-1}{n^2+2} = \frac{d}{dn}\left(\frac{n^2-1}{n^2+2}\right)\Delta n = \frac{6n}{(n^2+2)^2}\Delta n$$

Hence

$$\Delta n = \frac{(n^2+2)^2}{6n} k z$$

If n (Fig. 3) is the index of refraction of the already reacted solution

$$\frac{n_1}{n} = \frac{\sin \beta}{\sin \alpha} = \frac{\sin (\alpha+\Delta\alpha)}{\sin \alpha}$$
$$= 1 - \cot \alpha \sin \Delta\alpha$$

approximately, and therefore,

$$\cot \alpha \sin \Delta\alpha = 1 - \frac{n_1}{n} = \frac{\Delta n}{n}$$

or

$$\sin \Delta\alpha = \frac{\Delta n}{n \cot \alpha}$$

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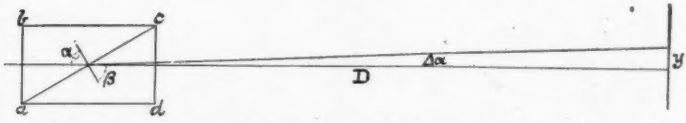

If D is the distance from the solution to the screen

$$\frac{y}{D} = \frac{\sin \Delta\alpha}{\cos \Delta\alpha}.$$
$$\therefore y = D \sin \Delta\alpha \text{ approximately}$$

Hence

$$y = \frac{D(n^2+2)^2}{n^2 \cot \alpha} k z$$

n does not vary more than ·1 per cent and if n lies between 1·3 and 1·4, which it usually does, the expression $\frac{(n^2+2)^2}{n^2}$ is practically constant.

Hence y is proportional to z, or the displacement of the image from its final position is proportional to the quantity of cane sugar in the solution.

Whether or not y is proportional to z in any particular case should and can be tested experimentally as follows. Take equal quantities by weight of a solution that has already reacted and of one that is just beginning to react. Mix them together and obtain a curve as above. This mixture is equivalent to a solution that has reacted half way, and the total change in the position of S_1 as indicated by the curve should be $\frac{1}{2}$ that in the case of the original solution. Such a curve photographed for the inversion of sugar proved the proportionality to within about $\frac{1}{2}$ of a per cent. If y is found not to be proportional to z a number of mixtures must be made with varying quantities of new and old solutions, and the relation between y and z determined.

The distances between the lines on the photographic plate corresponding to the different instants of time can be measured by means of a micrometer microscope of low power. I have found it more satisfactory, however, to place a glass scale over the plate and take the readings with a small lens, illuminating both scale and plate by means of a mirror below them.

The following table contains the results of such measurements on the plate representing the inversion of sugar. The first column contains the time t expressed in minutes; the second, the distances y in centimeters between the curve and the line drawn 24 hours later (the value of y for $t = 0$ being extrapolated), and the third, the percentage of cane sugar left in the solution.

t	y	% sugar	$\frac{k}{2{\cdot}3026}$
0	25·5	25·	·00535
15	21·2	20·78	
30	17·9	17·54	·00490
45	15·4	15·09	·00463
60	13·25	12·99	·00454
75	11·3	11·07	·00455
70	9·75	9·56	·00449
105	8·5	8·33	·00441
120	7·4	7·25	·00435
135	6·4	6·27	·00433
150	5·55	5·44	·00431
165	4·85	4·75	·00427
180	4·3	4·22	·00419
195	3·95	3·87	·00405
210	3·6	3·53	·00395
225	3·3	3·23	·00385

According to Gouldberg and Waage's law the rate at which the cane sugar disappears should be proportional to the amount left in the solution. Hence $\frac{dz}{dt} = -kz$

Or integrating between t_1 and t

$$k\,(t-t_1) = \log_e \frac{z_1}{z} = 2{\cdot}3026 \log_{10} \frac{z_1}{z}$$

or $$k = \frac{2{\cdot}3026}{t-t_1} \log_{10} \frac{z_1}{z}$$

The third column in the table contains the values of $\frac{k}{2{\cdot}3026}$ calculated by this formula, using the value $t_1 = 15$ minutes so as to avoid extrapolation. It appears that k as calculated above

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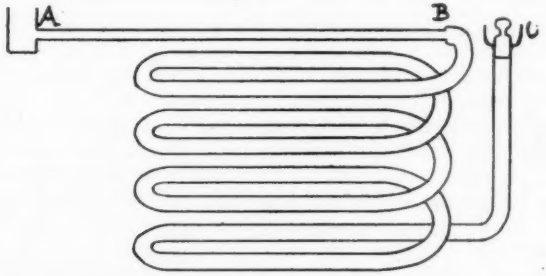

is not a constant. The decrease in its value indicates that the velocity of the reaction is greater at the beginning or less at the end than would be expected from Gouldberg and Waage's law. During the reaction, of course, the amount of water present changes perceptibly, but not enough to account for the large variation of k. The total change during the entire reaction is less than 2 per cent. The deviation from Gouldberg and Waage's law may be due to the relatively large quantity of hydrochloric acid in the solution. To decide whether it is or not will be the object of further investigation.

The second method is based upon the change in the volume of the chemical system during the reaction. In order to measure the change in volume the system is placed in a spiral glass tube (Fig. 4), on one end of which is sealed a capillary tube A B and on the other end a ground stopper and cup C. The reacting system may fill the entire spiral or only a part of it, the rest being filled with a liquid that does not combine with the given system. If the volume increases during the reaction, the cup A and most of the tube A B are filled with mercury. If the volume decreases, the cup and only a small part of the tube are filled. Evidently during the change of volume the mercury is drawn in or pushed out through the capillary tube and the positions of the end of the mercury column measure the amount of change.

The particular form represented (Fig. 4) was adopted, first, in order that the temperature of the system should remain that of a bath in which the spiral is immersed owing to the large surface presented to the bath; and second, in order that the tube might be filled, and the first reading of the position of the mercury column taken as soon after the reaction started as possible. The liquid is first poured in at C and allowed to fill the spiral, the tube A B and the cup A. Mercury is then poured into A and finally the stopper inserted at C. A little practice in manipulating the stopper and tilting the whole tube will enable one to set the dividing surface between the mercury and the other liquid at any desired point in the capillary tube. The tube A B is graduated or a graduated scale is fastened to it.

In most cases the change in the volume of a system is small. Hence, if the temperature of the apparatus varies during the reaction, even by a small amount, the consequent change in volume will be a large fraction perhaps of the change we wish to measure. It is, therefore, necessary to immerse the spiral tube in a delicate thermostat. In the following experiment on the inversion of a 25 per cent solution of cane sugar the electrical thermostat described by my assistant Mr. Lory and myself in this Journal for March, 1900, was used. The temperature of the bath did not vary as much as $\frac{1}{2000}$th of a degree except once, and then the variation was only about $\frac{1}{1000}$th of a degree.

In this experiment the spiral tube contained about 100^{cc} of the solution. The length of the capillary tube A B was 36^{cm}, and its cross section about $1^{sq\ mm}$. The temperature was 25°·872 C.

The first two columns of the following table contain the readings of the end of the mercury column, on a metal scale attached to the capillary tube, together with the corresponding intervals of time t in minutes.

After allowing the apparatus to stand 24 hours and the reaction to become practically completed, the bath was heated up again to 25°·872 C., allowing all of the mercury which had been drawn into the spiral to run out. The end of the mercury column then stood at the mark ·20, which is the zero corresponding to zero quantity of cane sugar in the solution. The third column in the table contains the readings referred to this zero.

Under the assumption that the volume of the solution is an additive function of the constituents, these latter distances representing the changes in volume should be proportional to the quantities of cane sugar left in solution. The last column

contains the values of $\frac{k}{2{\cdot}3026}$ calculated from the formula

$$\frac{k}{2{\cdot}3026} = \frac{1}{t-t_1} \log_{10} \frac{z_1}{z}$$

t	cm.	cm.	$\frac{k}{2{\cdot}3026}$
0			
20	34·55	34·35	
41	29·66	29·46	·00318
55	26·87	26·67	·00314
70	24·28	24·08	·00308
85	21·61	21·41	·00316
100	19·83	19·63	·00303
115	17·86	17·66	·00304
130	16·12	15·92	·00303
145	14·99	14·79	·00292
160	13·80	13·60	·00287
175	12·70	12·50	·00284
190	11·85	11·65	·00276
205	10·96	10·76	·00272
220	10·63	10·43	·00259
235	9·92	9·72	·00255
250	9·37	9·17	·00249
265	8·80	8·60	·00245

We see that k decreases, indicating as before that the velocity is less rapid at the end than would be expected from Guldberg and Waage's law.

If desired, a complete record of the position of the mercury column could be obtained by any of the methods for recording the readings of a mercury thermometer.

The chief advantages of the above described methods are, first that the chemical system is not disturbed during the reaction; second, that no time is lost in titration or other chemical tests for the state of the system, thus making it possible to investigate rapid reactions; third, that it is not necessary for the experimenter to make observations during the reaction, which is a tedious piece of work if the velocity is very small; and fourth, the curves are drawn by purely mechanical processes, thus avoiding the influence of the personal equation.

A third method based upon the change in the index of refraction of the chemical system as measured by the motion of interference bands is being perfected.

In conclusion I wish to thank my assistant, Mr. F. C. Blake, for the care with which he has helped me obtain the above data. He and his brother, Mr. J. C. Blake, are at work applying the methods to hitherto uninvestigated reactions.

Hale Physical Laboratory,
University of Colorado.

Art. XXIX.—*The Transmission of Sound through porous materials;* by F. L. Tufts, Ph.D.

A few years ago some experiments were made by the author for the purpose of determining the relative conductivities of different porous materials for sound waves. The methods employed at that time were comparatively crude, and while the data obtained could not be relied upon for great accuracy, they showed unmistakably that when two porous materials differ noticeably in the resistance offered to the transmission of sound, they also differ, in approximately the same way, in the resistance offered to the flow of a current of air through them.* When I attempted to obtain numerical results expressing the relative resistances offered by a number of different porous materials to the transmission of sound, I found that determinations made under different conditions gave results which varied to some extent. Some rather rough measurements of the relative resistances offered by these same materials to the transmission of air through them under different pressures, also showed variations greater than could be readily accounted for. It therefore seemed desirable to make a more careful comparison of the two phenomena.

For this purpose three different porous materials were selected, and in order not to introduce unnecessary complications, granular materials were chosen, the granules of which consisted of ordinary lead shot: a very considerable uniformity in the size and shape of the granules composing any one of the materials was thus obtained, and it was found that the packing of the material produced little or no difference in its conductivity. The coarsest material used consisted of a shot $4{\cdot}37^{mm}$ in diameter. This will be referred to as material A; an intermediate material composed of a shot $2{\cdot}79^{mm}$ in diameter will be designated by the letter B, and the material having the finest granules, a shot $1{\cdot}22^{mm}$ in diameter, will be called C. When a cylindrical vessel was filled with any one of these materials, it was found that about 40 per cent of the volume of the vessel was still occupied by air, and this percentage was practically the same whether the coarsest material, A, or the finest, C, was used.

In the first part of this paper, I shall describe the experiments for determining the variations in the resistances offered by the three materials A, B, and C, to the flow of air through them under different pressures. In the second part the

* Science (N. S.) ix, 219–220, 1899

experiments for determining the variations in the resistances offered by these same materials to the to and fro motion of the air particles of a sound wave will be given.

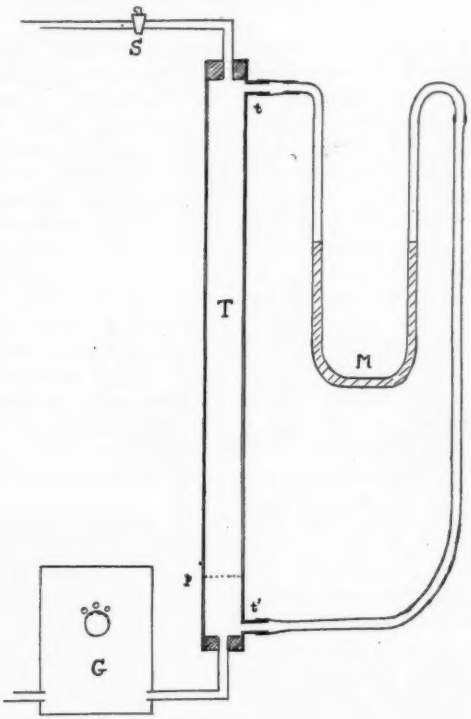

Fig. 1

Flow of air through granular materials.

The apparatus employed in studying the flow of air through the three sizes of shot is shown schematically in fig. 1. It consists essentially of a tube, T, about 75 centimeters long and 2·5 centimeters inside diameter, provided at p with a partition of wire gauze the meshes of which are fine enough to prevent the smallest shot from falling through. Near either end of this tube are connected side tubes, t and t', to which are attached respectively the two arms of a water manometer, M. The upper end of the tube, T, is connected though a cock, S, with a source of compressed air, and the lower end of the tube is connected to a gas-meter, G. In

using the apparatus the tube, T, would be disconnected from the source of compressed air, and one of the sizes of shot, B for example, poured into it till the desired length of shot column had been added. The tube would then be reconnected to the compressed air-pipe, and the cock, S, turned till the manometer indicated the desired difference in air pressure between the two ends of the column of shot. The rate of flow of air through the shot would be measured by noting with a stop-watch the time required for a definite volume of air, usually one cubic foot, to pass through the meter. The data recorded would be the size of shot, A, B or C; the length in centimeters of the column of shot in the tube; the difference in pressure between the two ends of the column, given by the manometer in centimeters of water, and the time in seconds required for a given volume of air to flow through the shot.

The first experiments were for the purpose of ascertaining the relation between the resistance offered by a granular material to the flow of air and the length or thickness of the material used. The length of a column of shot, C for example, was made equal to 10, 20, 30, etc. centimeters successively, and the difference in pressure between the two ends of the column was made respectively 1, 2, 3, etc. centimeters of water. Under these conditions the times required for a given volume of air to flow through the different lengths of the material were found to be equal.

For convenience in stating the results of these experiments, the term *pressure-gradient* will be used to designate the quotient obtained by dividing the difference in pressure between the two ends of a column of shot by the length of the column. It represents the difference in pressure per unit length of the material. Using this term, the results of the above experiments may be stated as follows:

For a given size of shot and a given pressure-gradient, the rate of flow of air through the shot is independent of the length of column used. This is equivalent to the statement that, other things being equal, the resistance offered by one of these materials to the flow of air through it, is directly proportional to the length or thickness of the material used.

Experiments were conducted with pressure-gradients ranging from $\frac{1}{30}$ to about $\frac{1}{3}$ of a centimeter of water per centimeter length of material, and the columns of shot were varied in length from 5 to 70 centimeters. All three sizes of shot were experimented with, and no marked deviation from the above law was found within these limits.

The next experiments were for the purpose of studying the relation between the increase in difference of pressure between the two ends of a column of shot, and the increased flow of air

through it. The data given in Table I are typical of the results obtained.

The length of the column of shot used in this particular case was 69 centimeters. The successive differences in pressure between the two ends of the column are given in centimeters of water in the first column of the table headed M. The columns headed A, B and C, give the times in seconds required for a tenth of a cubic foot of air to flow through the materials A, B and C respectively, under the corresponding differences in pressure indicated in the first column. The next three columns of the table contain the products of the pressures into the corresponding times of flow through the three sizes of shot A, B and C respectively. An examination of these products shows

TABLE I.

M	A	B	C	M×A	M×B	M×C	C/A	C/B
1	48·5	101·0	484·0	48	101	484	10·0	4·8
2	31·5	59·0	283·0	63	118	566	8·9	4·8
4	19·1	31·1	150·0	76	124	600	7·8	4·8
8	13·6	20·6	79·0	105	165	632	5·8	3·8
16	8·1	13·1	39·0	130	210	624	4·8	2·9
26	6·4	9·7	24·0	166	252	624	3·7	2·4

that the times of flow through the different materials decreases less rapidly than the pressure-gradient increases. This difference in rates is much more marked for the coarse materials, A and B, than for the finer material C, and for all of the materials is more noticeable for the lower than for the higher pressure-gradients. As a result of this, the ratio of the time required for a given volume of air to flow through C to the time required to flow through A or B at the same pressure, given in the columns headed C/A and C/B respectively, is seen to be different for different pressures. A comparison of these ratios shows that they decrease in value as the pressure-gradient increases. The results of the experiments may be summed up in the following statement:

As the pressure-gradient for either of the materials A, B or C is increased, the rate of flow of air through the material increases less rapidly than the pressure-gradient, within the range of pressures investigated. This difference of ratio of increase is more noticeable for the coarse than for the fine shot, and as a result of this, the numbers expressing the relative rates of flow of air through A and B as compared to C, become smaller as the pressure-gradient increases. This is equivalent to the statement that the resistances offered by the three sizes of shot to the flow of air through them, become more nearly equal as the pressure-gradient increases. The pressure-gradients used varied from 0·01 to 0·60 of a centimeter of water per centimeter length of material.

Flow of sound through granular materials.

These experiments were undertaken for the purpose of ascertaining if there were any variations in the resistances offered by the materials A, B and C, to the transmission of sound through them, corresponding to the variations already detected in the case of air currents. A number of different forms of apparatus were used in studying the relation between the resistance offered by such materials to the transmission of sound and the thickness of the material used. The form of apparatus which seemed least subject to disturbing influences is shown schematically in fig. 2.

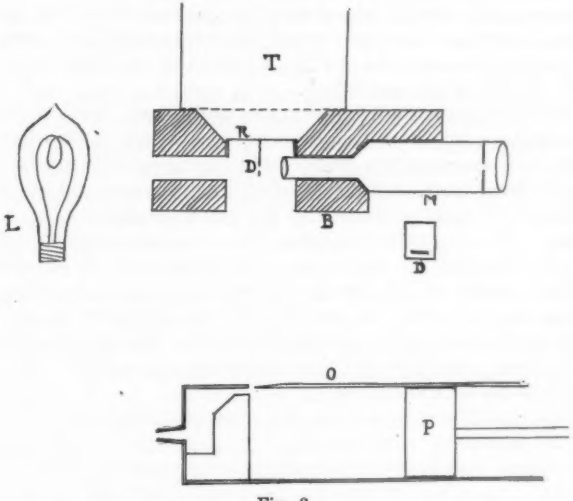

Fig. 2

It consists essentially of a thin rubber membrane R, stretched over a brass ring, which fits snugly in the opening through the block of wood, B. To the center of the membrane is attached a rectangular index of tinfoil, D, having a very narrow slit cut in it near its outer end. A microscope, M, provided with a micrometer ocular, is so mounted that it can be focused on the slit in the index, the slit being illuminated by a lamp, L. A tray, T, three centimeters deep, and about three centimeters in diameter, provided with a bottom of wire gauze, sits snugly on the block, directly over the membrane, and in it is placed the granular material under investigation. The application of a little cement around the edges of the tray makes an air-tight joint between it and the block, B. Thus the membrane together with the air in the tray above it forms

a single vibrating system, and any vibration of the membrane must be accompanied by a to and fro motion of the air in the tray. The block containing the membrane, microscope and tray was mounted on a suitable support, about fifty centimeters above an organ pipe, O, provided with a sliding piston, P, so that the effective length of the pipe could be varied, and the pipe thus brought in unison with the fundamental note of the apparatus above it. The organ-pipe was connected to a source of compressed air, and by means of a suitably placed stop-cock and manometer, the pressure at which the pipe was blown was kept constant. When the note emitted by the pipe was of about the same pitch with the fundamental note of the membrane, this would be set in quite violent vibration, and the amplitude of the vibration could be determined by measuring with the microscope the width of the band of light produced by the vibration of the slit, A.

A few preliminary experiments indicated that when the fundamental note of the membrane was as low as two hundred vibrations per second, no appreciable change in the fundamental note of the system, composed of the membrane and air in the tray above it, was produced by the gradual addition of shot to the tray. Under this condition, the diminution in the amplitude of vibration of the membrane, when shot is poured into the tray, is due chiefly to the increased resistance offered by the shot to the to and fro motion of the air particles, and only a very small amount is due to the slight change produced in the fundamental note of the system composed of the membrane and air in the tray.

In the experiments for the purpose of comparing the resistance of different thicknesses of the granular materials, the organ pipe was tuned to the vibrating system, R and T, and blown at a constant pressure. The amplitude of vibrations of the membrane was measured after each addition of a half centimeter thickness of shot. The differences between the reciprocals of these amplitudes should theoretically be proportional to the resistances offered by the various thicknesses of shot introduced. The data given in Table II are representative of the results obtained.

Table II.

T	A	B	C	A′	B′	C′	A′/T	B′/T	C′/T
0	60·0	60·0	60·0						
1	24·0	18·0	10·5	·0250	·0389	·0786	·0250	·0389	·0786
2	15·0	11·0	5·5	·0500	·0743	·1652	·0250	·0376	·0826
3	10·5	7·5	4·0	·0786	·1167	·2334	·0262	·0389	·0778
4	8·5	6·5	3·0	·1010	·1500	·3167	·0252	·0375	·0792
5	6·5	5·0	2·0	·1272	·1834	·4834	·0254	·0367	·0967
6	5·5	4·0	2·0	·1652	·2334	·4834	·0275	·0389	·0806

The note used in this particular case was about 150 vibrations per second. The numbers in the first column of the table headed T represent the thickness, in half centimeters, of the material in the tray. The next three columns, A, B and C respectively, contain the amplitudes of vibration of the membrane, in eightieths of a millimeter, after the addition to the tray of the corresponding thicknesses of the different materials A, B, and C respectively. The numbers given in the columns headed A′, B′, and C′, are obtained by subtracting the reciprocal of the amplitude of vibration with the empty tray in place, from the reciprocals of the amplitudes of vibrations when 1, 2, 3, etc. half centimeters of one of the three sizes of shot A, B, or C, had been placed in the tray. These numbers should be, theoretically, proportional to the resistances offered by 1, 2, 3, etc. half centimeters of the different materials used. In the last three columns of the table, headed A′/T, B′/T and C′/T, are given the quotients obtained by dividing these numbers by the corresponding thickness of the material. An examination of these quotients shows them to be practically constant for a given size of shot. The variations are no greater than can be accounted for by experimental errors, since the amplitudes of vibration could not be read to a greater accuracy than two or three units in the first place of decimals, thus making the percentage error greater for small than for large amplitudes. Experiments with much modified forms of the apparatus indicated the same relation between resistance and thickness. This relation may be stated as follows: The resistance offered by granular materials to the to and fro motion of the air particles in a sound-wave is proportional to the thickness of the material, other things being equal. Hence the relation between resistance and thickness is the same as was found to hold for direct currents of air.

Observations were also made upon the transmission of sound and of direct currents of air through porous materials of a woven texture, such as cheese cloth, cambric and cotton flannel, and also through materials like felting and cotton batting. With such materials it was much more difficult to obtain consistent results than with shot, owing to variations in packing. By subjecting the materials always to the same pressure, the variation due to packing was almost eliminated, and the results then showed that the resistance which such materials offered to the transmission of sound and of direct currents of air, was directly proportional to the thickness or number of layers of the material used, as was the case with granular materials.

For practical purposes, it is quite important to know the comparative opacity of equal thicknesses of different substances to sound waves, that is, the relative resistances they oppose to the transmission of sound. Determinations of the relative resistances offered by different materials showed considerable variations, according to the conditions under which the materials were compared. For example: a comparison of the resistances offered by the two sizes of shot, A and C, to the transmission of sound, made in another set of experiments, showed that when the materials were placed near the node of a stationary sound-wave the finer shot, C, opposed only twice as much resistance to the to and fro motion of the air particles as the coarser material A, while if the comparison was made near a loop, C offered over ten times as much resistance as A. Experiments are now in progress for the purpose of studying the variations in the relative resistances of the three materials, A, B and C, to the transmission of sound. The resistances offered by equal thicknesses of the different materials have been compared at different positions, with respect to the nodes of a stationary sound-wave. The results so far obtained seem to warrant the conclusion that the relative resistance of C, as compared to either A or B, varies according to the distance of the material from the node of the stationary sound-wave. Diminishing the distance from the node has the same effect upon the relative resistances of the materials to the transmission of sound that increasing the pressure-gradient has upon the relative resistances of the same materials to the transmission of air currents.

Physical Laboratory of Columbia University,
Nov. 17, 1900.

ART. XXX.—*On a Yoke with intercepted Magnetic Circuit for measuring Hysteresis;* by ZENO CROOK, A.M., Fellow in Physics, University of Nebraska.

HOPKINSON'S bar and yoke method of studying the magnetic hysteresis in iron necessitates either breaking the continuity of the magnetic circuit in the specimen to be examined or using the "step up" method. In many instances it is impossible to break the magnetic circuit as in the first method, while the "step up" method cannot be used when it is desirable to determine the magnetic flux without varying the same. For example, if we wish to study the effect on the magnetic

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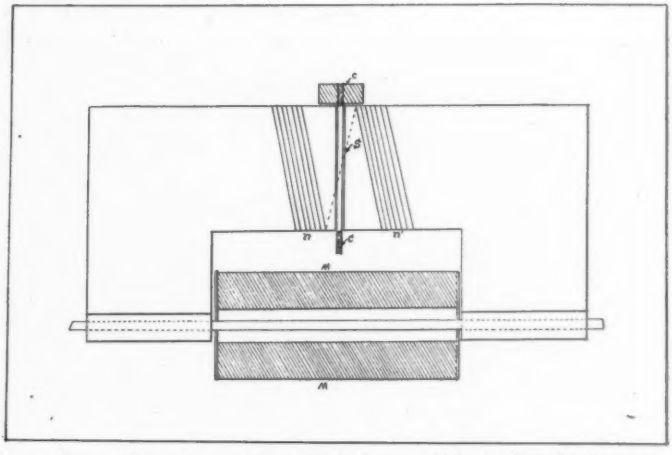

flux of an electric current it is impossible to break the magnetic circuit or vary the same during the observations. These difficulties may, however, be overcome by measuring the flux in the yoke itself. This method has been resorted to by Koepsel and others in direct-reading permeameters. In all these instruments, however, the air gap is so large that the reluctance of the circuit is very much increased.

These difficulties are overcome in a yoke designed by Professor D. B. Brace and constructed for him by Messrs. Siemens and Halske of Berlin. This yoke was forged from the best Norway iron and carefully annealed. Its cross-section is 100 □ cm. and the mean length of its magnetic circuit is 54^{cm}. It is divided into two like parts. The two halves, fig. 1, are mounted on a solid base and so arranged that the

slot S may be varied in width or be completely closed up at pleasure. Usually, however, the width is reduced to one or two-tenths of a millimeter. It was found that even within these narrow limits it was possible to use a test coil of sufficient number of turns to give accurate readings for weak fields. This coil C was constructed so that the total induction in the yoke would pass through it. It consisted of 125 turns of No. 46 double silk-covered wire between two thin sheets of mica. That part of the coil which had to pass through the slot was made of one layer of wire and the total thickness was such as to pass with perfect freedom through the slot when the latter was adjusted to a width not greater than ·025^{cm}. Its resistance was approximately 1000 ohms.

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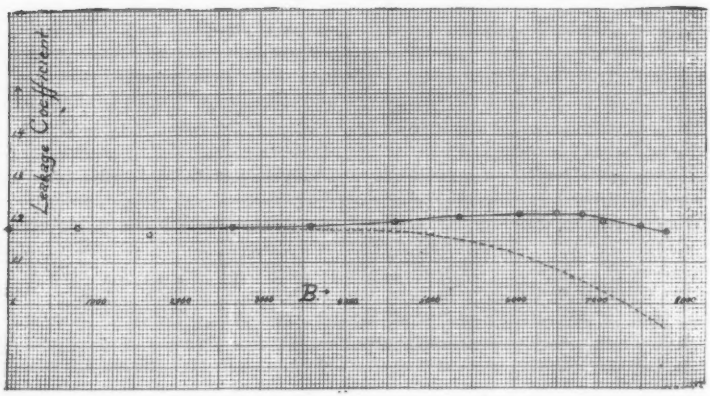

The specimens of iron or steel to be tested are shaped into cylindrical rods 40^{cm} long with a cross-section of ·28 □ cm. These fit into cylindrical grooves in the ends of the yoke and are clamped in place by iron covers and brass set screws. The magnetizing solenoid should be as small as possible. The solenoid which was used was constructed for another purpose and was much larger than necessary for bars of these dimensions. This solenoid "M" was 19^{cm} long and consisted of 1000 turns of No. 16 double covered copper wire. It was wound in nine layers on a brass spool, the inside diameter of which was 2·5^{cm}. The rod when in position is coaxial with this coil.

The induction in the yoke is easily measured by jerking the test-coil from the slot and reading the deflection produced on the ballistic galvanometer. To determine the induction in

the rod it is necessary to know the leakage coefficient of the yoke, or the ratio of the induction in the rod to that in the yoke. A test of the leakage coefficient for different inductions is shown in fig. 2.

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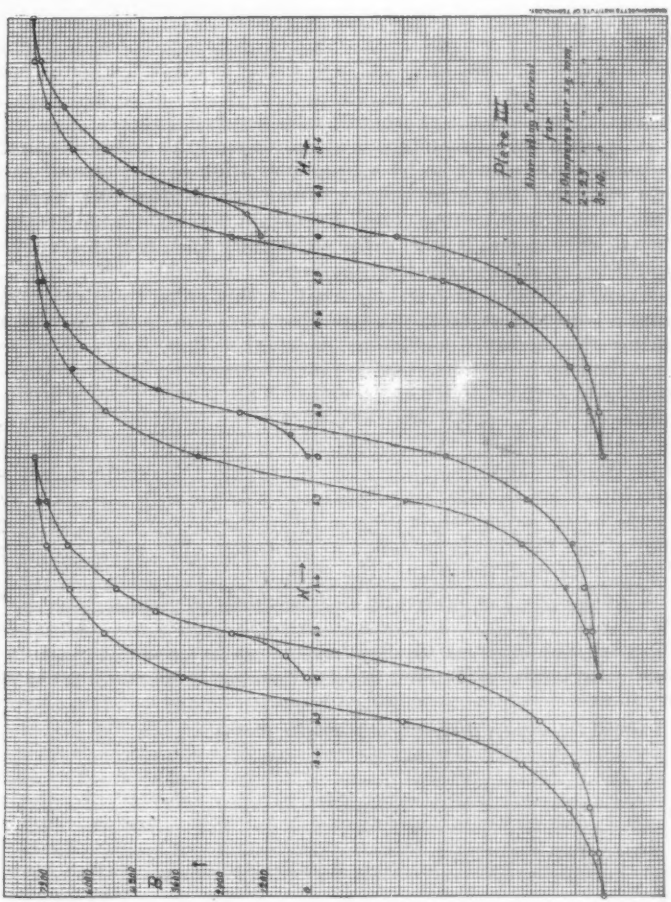

For observing its induction, a coil of fine wire was wound closely around the rod and the ends brought out and connected with a three-way switch, so that the induction for the same magnetizing current could be successively observed in the rod and in the yoke.

The first curve taken is represented by the dotted line. This shows that because of the large inside diameter of the magnetizing solenoid, as compared with the diameter of the rod, the induction in the yoke became greater than that in the rod when the rod approached saturation.

Compensating coils of a few turns were wound around the yoke, as shown by n and n', and were connected in series with the magnetizing solenoid. As the current increases in them they tend to increase the leakage of the yoke, and when properly adjusted by a suitable number of turns gave the curve of leakage coefficients represented by the full line.

It is seen that this curve is almost a straight line and could be made more nearly so by a proper relation of the size of the iron rod and the magnetizing solenoid. If the rod were a little larger or the magnetizing solenoid a little smaller the dotted curve would not drop so rapidly and the full curve would be more nearly a straight line.

Even with the proportions used in this yoke the deviation from a constant value is so small that the error is negligible in taking the leakage coefficient constant. This form of yoke may thus be used for scientific measurements, as it gives, practically, a perfect hysteresis cycle. This is well shown in the curves in fig. 3, which were obtained by multiplying the inductions in the yoke by this coefficient. The use of the yoke for studying the demagnetizing action of electric currents, without interrupting the magnetic circuit or varying the same by means of the solenoid, is illustrated in these curves. The first one gives the cycle when no alternate current is passing through the rod, the second the cycle when the current density is 2·5 amperes per square millimeter and the third when the current density is 10 amperes per square millimeter. The convenience and accuracy of this method for this class of measurements indicate its general utility over the more common type of yokes.

Physical Laboratory, University of Nebraska, Lincoln.

ART. XXXI.—*Mineralogical Notes;* by C. H. WARREN.

THE minerals which are described in this paper were presented for the purpose of study to the Mineralogical Laboratory of the Sheffield Scientific School by the gentlemen whose names appear beyond, and to whom the writer takes pleasure in expressing his thanks. The materials were kindly placed at the writer's disposal by Prof. S. L. Penfield, and the investigations were made in the Sheffield Mineralogical Laboratory while the writer was connected with that institution.

Anorthite Crystals from Franklin Furnace, N. J.

The first specimens received, showing the anorthite crystals, were found by Mr. Wm. Niven, of New York City, in the limestone quarry near the railroad station, at Franklin, and later some of the same mineral was received from Mr. Hancock, of Burlington, N. J. The crystals are of a dull gray color, tabular in habit and vary in size from individuals a few millimeters in diameter to large flat tables, $1\frac{1}{2}^{cm}$ long, 1^{cm} wide and 2 to 3^{mm} in thickness. They are few in number and are imbedded in the white crystalline limestone characteristic of that region. Flakes of graphite are plentifully sprinkled through the limestone and are plainly visible in the anorthite crystals themselves. As stated by Mr. Niven, the position in the quarry from which the specimens came was close to the contact of the limestone and the granite, and it is interesting to note here that anorthite has been noticed by Lacroix* as a contact mineral in limestones of the Pyrenees. It is probable that the Franklin mineral is of similar origin.

Although the faces of the crystals are dull and their solid angles and edges are somewhat rounded, sufficiently good reflections of the signal were obtained on some of the crystals to identify the following forms:

c	001,	*m*	110,	*y*	$\bar{2}01$,	*o*	$\bar{1}\bar{1}1$.
b	010,	*M*	$1\bar{1}0$,	*p*	$\bar{1}11$,		

Below are given the measured angles with the corresponding values calculated from the fundamentals established by Marignac.†

* Carte Géoligique de la France, No. 64, vol. x, 1898–9.
† Kk., Min. Russl., iv, 200, 1862.

	Measured.	Calculated.
$c \wedge b = 001 \wedge 010 =$	86°	85° 50′
$c \wedge m = 001 \wedge 110 =$	66	65 53
$c \wedge M = 001 \wedge 1\bar{1}0 =$	69 31′	69 20
$c \wedge y = 001 \wedge \bar{2}01 =$	80 48	81 14
$c \wedge p = 001 \wedge \bar{1}11 =$	54 20	54 17
$c \wedge o = 001 \wedge \bar{1}\bar{1}1 =$	59 (poor)	57 52
$b \wedge m = 010 \wedge 110 =$	58 15	58 4
$b \wedge M = 010 \wedge 1\bar{1}0 =$	62 23	62 26½
$m \wedge M = 110 \wedge 1\bar{1}0 =$	59 32	59 29

The accompanying figures, 1 and 2, illustrate the habits of the crystals.

On the base of some of the better crystals a series of fine striations can be seen, due to twinning after the pericline law. The trace of the rhombic section can be seen in the striations on the faces, *m*, 110, *M*, 1$\bar{1}$0, and *b*, 010. A section cut from

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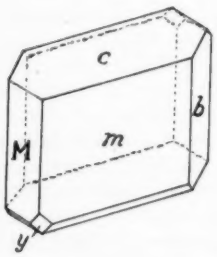

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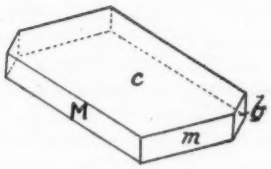

one of the crystals parallel to *c*, 001, when examined under the microscope, showed a considerable amount of calcite and other inclusions in addition to the flakes of graphite already alluded to. Some of these inclusions are undoubtedly water, as is indicated by the strongly marked, dark borders and by the presence of a considerable amount of water in the mineral as shown by the analysis. The extinction measured on the base, 001, using a Bertrand ocular and monochromatic light, was −40°.

A few of the smaller crystals were chosen for analysis. The included calcite was estimated by determining the amount of carbon dioxide evolved when the powdered mineral was treated with hydrochloric acid, and calculating from this the equivalent amount of calcium carbonate. After separating the silica in the usual manner it was dissolved in potassium hydroxide solution and thus separated from the small amount of graphite, which was afterwards weighed on a Gooch cru-

cible. The water was weighed directly by the method of Penfield.*

The results of the analysis are as follows:

					Mol. ratio.	
SiO_2	40·16%	÷	60	=	·669	2·00
Al_2O_3	34·89	÷	102	=	·342	1·02
CaO	18·26	÷	56	=	·326	·97
Na_2O	trace					
$CaCO_3$	5·30					
H_2O	1·69					
Graphite	·18					
	100·48					

The ratio of $SiO_2 : Al_2O_3 : CaO$ is nearly 2 : 1 : 1 as required by the formula of anorthite, $CaAl_2(SiO_4)_2$.

Feldspar Crystals, from Raven Hill, Cripple Creek, Colorado.

The feldspar crystals were collected by Dr. Whitman Cross of Washington, D. C., while engaged in making the geological survey of the Cripple Creek region. They occur in considerable numbers imbedded in a rather soft, light gray rock, apparently of phonolytic character, the exact nature of which is unknown, no petrographical study of the rock having thus far been made. It is light gray in color, much altered in appearance and occurs, as we are informed by Dr. Cross, as a narrow dike cutting through the andesitic breccia of Raven Hill, Prospect Shaft, on the eastern slope above the Moose Mine.

The feldspar crystals, which vary in size from individuals 5mm in length and 3mm in diameter to those 15mm in length, 10mm in width and 8mm in thickness, are of a light gray color like their matrix, and have undergone some alteration on their surface. The habit of the crystal is unusual in that the form y, $\bar{2}01$, is very prominent, while other forms b, 010; c, 001, and m, 110, are relatively small, fig. 3. Twinning after the Carlsbad law is common and gives rise to an appearance represented by fig. 4. In a large number of instances the crystals form peculiar aggregates, sometimes several crystals penetrating through each other. No simple twinning relations other than according to the Carlsbad law could be discovered.

The forms observed were: c, 001, b, 010, m, 110, and y, $\bar{2}01$, and below are the angles measured with a contact goniometer, also the calculated values.

* This Journal, xlviii, July, 1894.

		Measured.	Calculated.
$m \wedge m''' = 110 \wedge 1\bar{1}0$		$61°$	$61° 13'$
$m \wedge b = 110 \wedge 010$		$58\frac{1}{2}$	$59\ 23\frac{1}{2}$
$c \wedge m = 001 \wedge 110$		67	$67\ 47$
$c \wedge y = 001 \wedge \bar{2}01$		80	$80\ 18$

Sections parallel to both cleavages were prepared and showed on *b*, 010, an extinction of +9° to +10°, and on *c*, 001, one approximately parallel to the *a* axis. Under crossed nicols the sections show a difference of shading or cloudiness, indicating that the crystals are not of homogeneous structure. Kaolinization has commenced to some extent and a small amount of a

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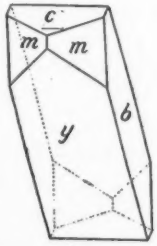

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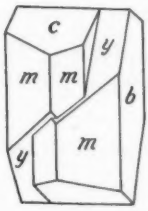
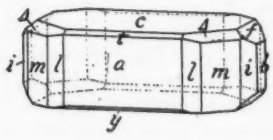


white lustrous mica can be seen. The large extinction-angle, +9° to +10° on 010, would seem to indicate a soda-orthoclase.

Crystals of Iron Wolframite from South Dakota.

The Wolframite crystals were sent by Mr. W. M. Foote of Philadelphia, Pa., but the exact locality from which they were obtained could not be ascertained. The crystals, the largest of which are about 4^{mm} long and not over 1^{mm} in thickness, are found filling numerous small cavities in a highly siliceous rock. They are elongated in the direction of the ortho-axis, and, as the ortho-pinacoid and base are the most prominent forms, the crystals present the appearance of a nearly rectangular prism. This prism is given a wedge-shaped termination by the development of the several prism faces, as can be seen from fig. 5. The majority of the crystals show a decided vicinal development of their faces and other irregularities. By using a strong illumination and the δ ocular with a Fuess reflection goniometer satisfactory measurements were obtained from one of the smaller and more perfect crystals. The following forms were identified, of which the prism *i*, 7·11·0, is new:

5



a	100,	*c*	001,	*s*	210,	*t*	102,	*f*	011
b	010,	*m*	110,	*i*	7·11·0,	*y*	$\bar{1}02$,	Δ	112

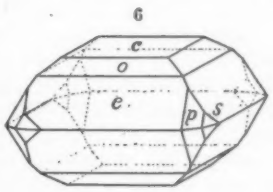
The measured angles and their corresponding calculated values are given beyond, the later being taken from the fundamentals established by Des Cloiseaux* for wolframite:

			Measured.	Calculated.
$a \wedge c$	=	$100 \wedge 001$ =	89° 25′	89° 21′
$m \wedge m'$	=	$110 \wedge \bar{1}10$ =	100 19	100 37
$m \wedge b$	=	$110 \wedge 010$ =	50 22	50 18½
$l \wedge l'$	=	$210 \wedge \bar{2}10$ =	134 45	134 55½
$i \wedge i'$	=	$7\bar{1}1\cdot0 \wedge \bar{7}11\cdot0$ =	74 51	74 59
$a \wedge t$	=	$100 \wedge 102$ =	61 45	61 54
$a \wedge y$	=	$100 \wedge \bar{1}02$ =	63 8	62 54
$a \wedge f$	=	$100 \wedge 011$ =	89 35	89 31
$m \wedge \Delta$	=	$110 \wedge 112$ =	55 34	55 28

Considering the character of the faces the foregoing measured and calculated values show a satisfactory agreement. The chief interest connected with this mineral is that it gives almost no reaction for manganese, indicating that its composition is very nearly that of an iron tungstate, $FeWO_4$. So far as known to the writer, it is the first occurrence of a variety of this mineral free from manganese, and it is to be hoped that more may be learned of its place of occurrence.

Pseudomorphs of Wolframite after Scheelite from Trumbull, Conn.

Pseudomorphs of wolframite after scheelite have been known for some time to occur at Trumbull, Conn., where they are found in a highly siliceous vein associated with pyrite and a little native bismuth. The pseudomorphs attain a considerable size, sometimes measuring 3 or 4^{cm} in diameter, and usually present the habit of the simple pyramid common to scheelite, *p*, 111, often modified by the pyramid of the second order *e*, 101. The accompanying figure represents a somewhat more complicated habit and was drawn from a fine crystal kindly loaned by Mr. Lazard Cahn of New York. The most prominent form is *e*, 101, truncated by *o*, 102, and terminated by a basal plane *c*. The corners are modified by pyramids, of the first order *p*, 111, and of the third order *s*, 131. The angles of the crystal measured with a contact goniometer show a satisfactory agreement with the corresponding angles given for scheelite. A number of crystals showed, on breaking, a light colored core of scheelite still remaining within the black exterior of wolframite.



* Am. Ch. Phys., xix, 168, 1870.

ART. XXXII.—*On the Expansion of Certain Metals at High Temperatures;* by LUDWIG HOLBORN and ARTHUR L. DAY.

[Communication from the Physikalisch-Technische Reichsanstalt, Charlottenburg, Germany.]

THE expansion of bodies at high temperatures has been so little studied that the records are few and only indifferently accurate. We therefore devised a new method and applied it to the determination of the expansion of platin-iridium and of porcelain up to 1000° for use in our recent measurements with the gas thermometer and extended it afterward to various other metals. Platinum, palladium and nickel were investigated up to the same temperature, silver to near its melting point, constantan to 500° and finally a single sort each of iron and steel to 750°, these being of especial interest not only on account of their special magnetic properties, but on account of their wide technical application.

On account of the difficulty in heating considerable lengths of a metal uniformly, observations have usually been made heretofore upon short pieces with necessarily diminished accuracy, or the attempt at uniform heating has been entirely abandoned and the bar allowed to project out of the oven at both ends, these cold ends being provided with the marks upon which the expansion observations are made. In the latter case the mean temperature of the bar is determined with the gas thermometer or by an electrical resistance method.

This method has the disadvantage that the variation of the expansion with the temperature cannot be properly observed.

The arrangement of the apparatus in our experiments has been already described.* A bar one-half meter in length, of the metal to be investigated, is enclosed in an electrically heated porcelain tube considerably longer than the bar. In this way we obtained not only expansions of considerable magnitude (as much as 9^{mm} in some cases), but also a very uniform temperature along the bar, the exact distribution of which was measured and not merely a mean value.

Measurement of the Length.—The expansion was measured with the eye-piece micrometers of two fixed microscopes arranged to observe certain marks near the ends of the bar. The whole system was so solidly mounted upon a heavy stone pillar that after several days' observing no displacement of the microscopes could be observed equal in magnitude to the errors of observation. The differences observed between the

* Ludwig Holborn and Arthur L. Day, this Journal (IV), lvii, 171, 1900, also Annalen der Physik, ii, 505, 1900.

lengths of the various bars before and after heating consequently correspond to permanent variations in the lengths of the bars. This fact was also several times confirmed by measurements before and after heating, with a comparator.

An accidental disturbance of the adjustment is not wholly impossible however, and we therefore referred the expansion to the length of the cold bar as observed immediately before the heating rather than after, as the latter measurement could not be made until the following day after the oven had cooled down. The amounts of such slight differences as were observed are recorded in their proper places. The preliminary heating of the bar to remove mechanical strains and inhomogeneities in the metal is not taken into account of course in this connection. The permanent change in the length of a new bar after the first heating is often very considerable, hence each bar was always first subjected to a single preliminary heating to the highest temperature to be used in the subsequent measurements.

It may be further mentioned that the length represented by one turn of the micrometer screw was determined directly from the readings at the temperature of the room, the interval between the marks on the bar having been determined independently in advance upon the comparator.

The remaining details of the length measurement will appear from the example given in detail further on.

Measurement of the Temperature.—During the expansion observations the temperature of the middle of the bar alone was measured, a thermo-element whose bare hot junction lay upon the bar at its middle point being used for the purpose. The fall in the temperature toward the ends was determined separately by observations at points on each side of the center, the element being moved along the bar and the differences as compared with the center measured by direct comparison.

Two different oven tubes were used in the course of the series of observations here described. The first was wound with nickel wire 2^{mm} in diameter and proved fairly satisfactory, but in the hope of increasing the uniformity of temperature distribution a second tube was prepared with $1{\cdot}2^{mm}$ wire in trifilar winding, which proved much better. We also tried rewinding the first coil with the heavier wire, but soon became convinced that although it is much more durable it is less well adapted to heating such a long and slender tube.

It is a matter of the greatest care to arrange the windings on such a tube so as to produce uniform temperature distribution. Some very painstaking trials yielded considerably poorer results than those here communicated. On the second tube mentioned, and the most successful one we obtained, the windings

are considerably nearer together toward the ends than in the center, but to compensate, the fall in temperature near the two openings through which the observations were made, is hardly possible without tremendously over-compensating the adjoining sections. The reason lies in the fact that one whole turn of wire is lost at the openings.

The presence of the bar also contributed something toward equalizing the temperature through its own conductivity. This was especially noticeable in the case of silver (6^{mm} in diameter) when compared with platinum and palladium (each 5^{mm} in diameter), for example.

Table I contains observations of the temperature distribution in the two tubes.

Nickel is included with this series for a special reason. Between the two measurements with nickel to 750° a considerable interval of time intervened, during which the oven was used for other purposes. These two series therefore show very clearly that the distribution of temperature suffers little from the oxidation of the oven coil with use.

Table I shows the differences of temperature in microvolts observed at eight points along the bar as compared with the middle. The relation between the thermo-electric force and the temperature for the element used is contained in Table XVI of the original investigation (loc. cit., p. 186). The temperature gradient is then obtained graphically and the mean, Δ, algebraically added to the reading at the middle point to obtain the mean temperature of the bar.

The observations were always begun with a series of readings at the temperature of the room, which was measured by introducing a mercury thermometer into the oven tube, then at the points 250, 500, 750 and 1000° as nearly as the oven could be regulated. In certain cases the intermediate temperatures 375, 625 and 875° were also observed. No point below 250° was attempted on account of the diminished sensitiveness of the thermo-element at the lower temperatures. For observations in this region it would be better to substitute a bath for which the arrangement of the apparatus and the heating arrangements could be readily adapted. It would indeed be perfectly possible to carry on these observations in a niter bath to above 600° with a perfectly uniform distribution of temperature throughout the length of the bar by properly insulating the oven coil.

1. *Platinum.*

The platinum bar, as well as the two immediately following, were prepared from chemically pure material and placed at our disposal through the courtesy of the firm of Heräus in Hanau,

TABLE I.

Temperature Distribution in the Oven (in Microvolts).

From center of oven.	Platinum.							
	Oven Tube I.				Oven Tube II.			
	250°	500°	750°	1000°	250°	500°	750°	1000°
6cm East	− 22	− 10	+ 17	0	+10	+ 35	+ 46	+ 77
12 "	− 33	− 23	+ 27	+ 25	+56	+125	+183	+227
19 "	−170	−230	−250	−443	+79	+157	+189	+171
23 "	−282	−310	−610	−900	−79	−196	−248	−411
6cm West	+ 57	+170	+230	+335	− 5	+ 9	+ 49	+ 99
12 "	+ 73	+220	+315	+540	+38	+135	+238	+342
19 "	− 62	− 5	0	+ 53	+89	+227	+345	+398
23 "	−210	−250	−380	−480	−12	+ 42	− 9	−143
Δ	− 44	− 11	+ 4	+ 51	+25	+ 64	+116	+135

Temperature Distribution in the Oven (MV).

From center of oven.	Oven Tube II.							
	Palladium.				Silver.			
	250°	500°	750°	1000°	250°	500°	750°	875°
6cm East	+ 13	+ 29	+ 55	+ 80	+ 3	+ 21	+ 35	+ 19
12 "	+ 59	+128	+180	+236	+47	+107	+150	+142
19 "	+ 80	+155	+188	+164	+78	+140	+163	+125
23 "	−100	−165	−210	−402	−84	−174	−220	−344
6cm West	− 1	+ 12	+ 53	+ 94	+ 1	+ 15	+ 52	+ 20
12 "	+ 52	+148	+269	+356	+23	+ 82	+153	+177
19 "	+ 95	+233	+358	+399	+48	+133	+217	+223
23 "	+ 12	+ 34	− 3	−129	+ 3	+ 48	− 29	+ 11
Δ	+ 31	+ 77	+124	+135	+16	+ 49	+ 80	+ 62

From center of oven.	Oven Tube II.—Nickel.					
	250°	375°	500°	750°	750°	1000°
6cm East	+16	+ 22	+ 27	+ 59	+ 57	+ 82
12 "	+64	+ 91	+124	+196	+191	+258
19 "	+89	+117	+147	+194	+168	+196
23 "	−87	−111	−150	−205	−226	−337
6cm West	+ 4	+ 15	+ 26	+ 64	+ 75	+120
12 "	+55	+110	+163	+303	+333	+458
19 "	+90	+177	+248	+405	+445	+509
23 "	+13	+ 20	+ 21	− 29	− 26	−221
Δ	+38	+ 74	+109	+152		+185

Germany. Some 5^{mm} from the end of each bar plane surfaces were filed and polished upon it in the plane of the axis and upon these five fine divisions were ruled at millimeter intervals. The bar of platinum, which was 5^{mm} in thickness, was measured in both the oven tubes described.

By way of example, a full series of actual readings of the microscope is contained in Table I*a*. The micrometer readings are represented by F and F′ for the fixed wires, I, II, . . . V and I′, II′, . . V′ for the settings of the movable wires upon the ruled divisions on the two ends of the bar respectively. The temperatures in degrees or microvolts are contained under *t*.

At each temperature (20°, 250°, 500°, 750°, 1000° and then 19° after the oven had cooled down) two sets of readings were made each containing settings upon each division of the bar and the fixed microscope cross-wire in their proper succession—the first in the forward, the second in the backward direction of the micrometer screw. This symmetry served to minimize the effect of a slight creeping of the bar such as was often noticeable at the higher temperatures. The series also included five observations of the temperature at proper intervals.

From the observations the displacement of the various divisions during the change of temperature from *t* to *t*′ was calculated and is entered for each separately in Table I*b*. A positive sign indicating that the displacement has taken place toward the end being read. The columns *M* and *M*′ contain the intervals expressed in turns of the micrometer screw (*r* and *r*′) and the corresponding values reduced to millimeters, the sums being then brought together under Σ. For the remaining observations only the values of *M*, *M*′ and Σ are given. Table I*c* contains these values for the observations made upon the platinum bar which was heated in the first oven tube on the first two days and in the second on the remaining. It will be seen that the corresponding values of Σ agree extremely well.

The Σ values are then corrected slightly to correspond to the round numbers 0°, 250°, etc., by the use of an approximate formula for the expansion λ_s of the bar from which the required values of $\frac{d\lambda_s}{dt}$ were obtained.

The values of *t* observed at the middle point of the bar require to be corrected for the fall in temperature toward the ends as described above. These are contained in Table I*d*, in which only Σ', the mean of each two corresponding values of Σ, is given.

TABLE I *a*.

Observations upon Platinum Bar, June 16, 1900.

t		20·3°		
I	6·328	6.327	6·329	6·329
II	6·950	6·971	6·956	6·962
III	7·846	7·851	7·837	7·848
F	8·527	8·530	8·523	8·529
IV	8·787	8·787	8·781	8·790
V	9·634	9·642	9·638	9·648
	↓	↑	↓	↑
I′	0·725	0·728	0·720	0·723
II′	1·683	1·682	1·680	1·684
III′	2·638	2·636	2·632	2·632
F′	3·000	2·993	2·991	2·999
IV′	3·586	3·583	3·581	3·588
V′	4·247	4·242	4·230	4·240
t				20·3°

t	1814 MV		1812	1830
I	5·743	5·743	5·746	5·740
II	6·369	6·374	6·374	6·370
III	7·259	7·261	7·250	7·257
IV	8·199	8·200	8·199	8·191
F	8·533	8·536	8·529	8 529
V	9·053	9·059	9·049	9·054
	↓	↑	↓	↑
I′	1·070	1·077	1·061	1·068
II′	2·029	2·037	2·029	2·028
III′	2·991	2·992	2·991	2·990
F′	2·991	2.992	2·991	2·990
IV′	3·941	3·942	3·943	3·939
V′	4·596	4·600	4·595	4·596
t	1814 MV		1825	

t	4131 MV		4134	4151
I	4·489	4·488	4·487	4·480
II	5·112	5·116	5·113	5·114
III	6·000	5·999	6·001	6·000
IV	6·941	6·939	6·937	6·938
V	7·798	7·801	7·798	7·801
F	8·531	8·533	8·537	8·532
	↓	↑	↓	↑
I′	0·865	0·869	0·862	0·859
II′	1·831	1·830	1·827	1·830
III′	2·783	2·788	2·779	2·788
F′	2·995	2·997	2·998	2·999
IV′	3·749	3·748	3·746	3·744
V′	4·403	4·401	4·398	4·402
t	4132 MV		4144	

t	6600 MV		6605	6625
I	3·211	3·184	3·187	3·162
II	3·840	3·821	3·811	3·791
III	4·728	4·710	4·699	4·687
IV	5·666	5.653	5·642	5·629
V	6·529	6·511	6·499	6·491
F	8·531	8·531	8·529	8·527
	↓	↑	↓	↑
I′	0·685	0·675	0·645	0·639
II′	1·647	1·637	1·613	1·607
III′	2·607	2·590	2·576	2·572
F′	2·991	2·999	2·991	3·000
IV′	3·567	3·562	3·539	3·538
V′	4·225	4·220	4·198	4·195
t	6596 MV		6616	

t	9412 MV		9423	9436
I	1·618	1·582	1·581	1·561
II	2·241	2·218	2·207	2·196
III	3·139	3·113	3·100	3·092
IV	4·070	4·049	4·043	4·036
V	4·931	4·914	4·917	4·901
F	8·530	8·537	8·535	8·532
	↓	↑	↓	↑
I′	0·298	0·287	0·275	0·256
II′	1·262	1·250	1·222	1·211
III′	2·219	2·219	2·191	2·181
F′	2·989	2·999	2·990	2·996
IV′	3·192	3·198	3·150	3·141
V′	3·855	3·852	3·819	3 816
t	9432 MV		9428	

t		19·3°		
I	6·762	6·767	6·768	6·770
II	7·393	7·391	7·389	7·392
III	8·263	8·280	8·275	8·281
F	8·531	8·540	8·538	8·537
IV	9·210	9·213	9·212	9·218
V	10·059	10·073	10·071	10·078
	↓	↑	↓	↑
I′	1·190	1·180	1·181	1·182
II′	2·133	2·147	2·148	2·149
F′	2·997	2·994	2·989	2·998
III′	3·107	3·103	3·107	3·105
IV′	4·048	4·048	4·051	4·044
V′	4·703	4·708	4·702	4·712
t				19·3°

TABLE I *b*.

Observations upon Platinum Bar, June 16, 1900.

t	*t'*	I	II	III	IV	V	Mean M		$\Sigma = M + M'$ mm.
							r	mm.	
20·3°	1813 MV	0·591	0·595	0·592	0·593	0·588	0·592	0·669	1·044
20·3	1822	0·589	0·590	0·592	0·594	0·594	0·592	0·669	1·044
1813 MV	4132	1·251	1·255	1·255	1·257	1·253	1·254	1·417	1·200
1822	4143	1·265	1·264	1·259	1·263	1·258	1·262	1·425	1·206
4132	6600	1·290	1·282	1·280	1·279	1·279	1·282	1·449	1·258
4143	6615	1·302	1·306	1·301	1·295	1·298	1·300	1·469	1·247
6600	9422	1·601	1·604	1·596	1·623	1·600	1·605	1·812	1·417
6615	9429	1·610	1·605	1·603	1·602	1·592	1·602	1·810	1·413
19·3°	20·3°	−0·430	−0·424	−0·419	−0·418	−0·421	−0·422	−0·477	0·008
19·3	20·3	−0·428	−0·420	−0·423	−0·417	−0·420	−0·422	−0·477	0·014
t	*t'*	I′	II′	III′	IV′	V′	Mean M′		
							r'	mm.	
20·3°	1813 MV	0·352	0.355	0·360	0·362	0·358	0·357	0·375	
20·3	1822	0·347	0·351	0·363	0·360	0·365	0·357	0·375	
1813 MV	4132	−0·221	−0·206	−0·210	−0·197	−0·200	−0·207	−0·217	
1822	4143	−0·212	−0·208	−0·215	−0·204	−0·204	−0·209	−0·219	
4132	6600	−0·176	−0·188	−0·186	−0·183	−0·178	−0·182	−0·191	
4143	6615	−0·220	−0·220	−0·211	−0·207	−0·204	−0·212	−0·222	
6600	9422	−0·386	−0·385	−0·379	−0·369	−0·368	−0·377	−0·395	
6615	9429	−0·369	−0·386	−0·381	−0·386	−0·371	−0·379	−0·397	
19·3°	20·3°	0·459	0·458	0·470	0·464	0·462	0·463	0·485	
19·3	20·3	0·463	0·468	0·475	0·464	0·473	0·468	0·491	

TABLE I *c*.
Platinum Bar.

	t	M (mm.)	M′ (mm.)	Σ (mm.)	*t*	M (mm.)	M′ (mm.)	Σ (mm.)
Feb. 24	19·9°				19·9°			
	1900 MV	0·799	0·249	1·048	1912 MV	0·799	0·257	1·056
	4255	0·680	0·541	1·221	4265	0·653	0·564	1·217
	6830	0·312	0·990	1·302	6838	0·294	0·985	1·279
	9649	1·143	0·239	1·382	9660	1·213	0·198	1·411
Feb. 27	17·8°				17·8°			
	1920 MV	0·794	0·275	1·069	1926 MV	0·798	0·280	1·078
	4250	0·548	0·664	1·212	4256	0·554	0·645	1·199
	6823	0·525	0·759	1·284	6823	0·498	0·786	1·284
	9639	1·022	0·345	1·367	9631	1·055	0·334	1·389
June 16	20·3°				20·3°			
	1813 MV	0·669	0·375	1·044	1822 MV	0·669	0·357	1·026
	4132	1·417	−0·217	1·200	4143	1·425	−0·219	1·206
	6600	1·449	−0·191	1·258	6615	1·469	−0·222	1·247
	9422	1·812	−0·395	1·417	9429	1·810	−0·397	1·413
June 20	20·1°				20·1°			
	4190 MV	2·634	−0·375	2·259	4200 MV	2·638	−0·379	2·259
	6564	1·381	−0·156	1·225	6570	1·403	−0·186	1·217
	9365	1·736	−0·328	1·408	9384	1·751	−0·343	1·408

TABLE I *d*.
Platinum Bar.

t	Σ′ (mm.) Oven Tube I. Feb. 24.	Σ′ (mm.) Oven Tube I. Feb. 27.	Σ′ (mm.) Oven Tube II. June 16.	Σ′ (mm.) Oven Tube II. June 20.	λ (mm.) Observed.	λ (mm.) Calculated.
0°					0	0
250	1·111	1·114	1·116	2·289	1·114	1·112
500	1·196	1·192	1·184		2·301	2·304
750	1·271	1·268	1·270	1·285	3·574	3·576
1000	1·344	1·334	1·386	1·377	4·934	4·928

In connection with this table it should be mentioned that the platinum bar was heated for the first time on Feb. 23, when $\lambda_s = 2{\cdot}306^{mm}$ was observed at 500° and $\lambda_s = 4{\cdot}986$ at 1000°. After cooling, an increase in the total length amounting to $0{\cdot}084^{mm}$ was measured. These permanent changes in the length of the bar for the subsequent four days' observations contained in the table were 0·020, 0·028, −0·007 and −0·004 respectively.

The agreement in the observations up to 750° is most satisfactory throughout; in the interval between 750° and 1000°, however, a discrepancy appears between the observations in the two oven tubes amounting to 1 per cent of the total expansion. The expansion λ_s of the bar (in μ) may be expressed by the quadratic formula

$$\lambda_s = 4{\cdot}288t + 0{\cdot}000640t^2 \ (\mu)$$

The mean distance between the marks on the two ends amounted to 483·5^{mm} at 0°, hence the expansion* of a unit bar would be

$$\lambda = \{8868t + 1{\cdot}324t^2\}10^{-9}$$

Benoît† obtained for the expansion of pure platinum measured between the temperatures 0° and 75° by Fizeau's method, the formula

$$\lambda = \{8901t + 1{\cdot}21t^2\}10^{-9}$$

The expansions obtained by extrapolation of this formula do not differ from ours by an amount equal to 1 per cent until 1000° is reached—a remarkable agreement considering the magnitude measured and the range of temperature involved.

2. *Palladium.*

The measurements upon palladium are contained in Tables II*a* and II*b* and were all made in the second oven tube except the preliminary heating at the beginning. For this, values of

TABLE II*a*.

Palladium Bar.

	t	M (mm.)	M′ (mm.)	Σ (mm.)	t	M (mm.)	M′ (mm.)	Σ (mm.)
June 26	19·6°	1·349	0·036	1·385	19·6°	1·362	0·018	1·380
	1810 MV	1·432	0·176	1·608	1819 MV	1·434	0·177	1·611
	4083	1·197	0·526	1·723	4098	1·198	0·515	1·713
	6571	1·689	0·197	1·886	6585	1·718	0·172	1·888
	9339				9343			
June 28	18·8°	1·212	0·239	1·451	18·8°	1·199	0·252	1·451
	1923 MV	1·305	0·224	1·529	1927 MV	1·347	0·198	1·545
	4072	1·928	−0·205	1·723	4085	1·934	−0·222	1·712
	6552	2·313	−0·424	1·889	6555	2·322	−0·428	1·894
	9345				9348			

* The earlier formula published elsewhere (loc. cit., p. 174) was based upon the observations with the first oven tube only.

† Benoît, Trav. et Mem. du Bureau international, vi, 1, 1888.

TABLE II *b*.

Palladium Bar.

t	Σ' (mm.) June 26.	Σ' (mm.) June 28.	λ_s (mm.) Observed.	λ_s (mm.) Calculated.
0°			0	0
250	1·476	1·470	1·473	1·475
500	1·611	1·616	3·087	3·082
750	1·729	1·739	4·821	4·821
1000	1·878	1·858	6·689	6·692

the expansion at 250°, 500° and 750°, equal to 1·617, 1·720 and 1·840 respectively, were obtained. A permanent increase in length after the preliminary heating amounting to 0·024^{mm} was observed; the permanent changes after succeeding heatings in no case amounted to 0·01^{mm}.

The expansion of the bar employed may be represented by

$$\lambda_s = 5{\cdot}636t + 0{\cdot}00106t^2(\mu)$$

Its length at 0° was 482·9, whence

$$\lambda = \{11670t + 2{\cdot}187t^2\}10^{-9}$$

3. *Platin-iridium* (*80 Pt, 20 Ir*).

The series of measurements upon the platin-iridium bar which are contained in the Tables III*a* and III*b* were all made

TABLE III *a*.

Platin-iridium Bar.

	t	M (mm.)	M′ (mm.)	Σ (mm.)
Jan. 19	16·9°			
	1810 MV	0·348	0·595	0·943
	4193	0·850	0·318	1·168
	6757	0·636	0·592	1·228
	9514	0·969	0·322	1·291
	9569	1·045	0·276	1·321
	9560	1·043	0·273	1·316
Jan. 24	17·9°			
	1862 MV	0·675	0·291	0·966
	4181	0·654	0·462	1·116
	6708	0·607	0·604	1·211
	9528	1·163	0·189	1·352
Jan. 26	18·8°			
	1843 MV	0·557	0·406	0·963
	4170	0·664	0·456	1·120
	6705	0·411	0·813	1·224
	9527	1·786	−0·450	1·336
	9539	1·797	−0·463	1·334

TABLE III *b*.

t	Σ' (mm.) Jan. 19.	Jan. 24.	Jan. 26.	λ_s (mm.) Observed.	Calculated.
0°	1·031	1·033	1·034	0	0
250	1·130	1·111	1·110	1·033	1·033
500	1·202	1·204	1·213	2·150	2·151
750	1·277	1·308	1·294	3·357	3·355
1000	1·280		1·287	4·645	4·645
	1·280				

in the first oven tube. Being the first observations made, the above described scheme was not exactly followed. For the temperatures below 1000° only a single set of measurements was made upon this bar; it had received a preliminary heating like the others however. The length at 0° was 483·1^{mm} and the formulæ are

$$\lambda_s = 3{\cdot}960t + 0{\cdot}000685t^2 (\mu)$$
$$\lambda = \{ 8198t + 1{\cdot}418t^2 \} 10^{-9}$$

4. *Silver.*

The silver bar was 6^{mm} in thickness and carried seven divisions at each end, notwithstanding which the expansion was so great that not all the divisions were visible at all temperatures.

The preliminary heating was carried up to 900° and the permanent increase in the length which resulted amounted to 0·13^{mm}. The silver became very soft at this temperature and could with difficulty be prevented from sagging slightly. Partly for this reason probably, and partly because the permanent changes in the length after heating were larger than with any of the other bars, the observations at the higher temperatures disagree somewhat more widely among themselves. The last observation at 875° is not included in the calculation. The

TABLE IV *a*.
Silver Bar.

	t	M (mm.)	M′ (mm.)	Σ (mm.)	t	M (mm.)	M′ (mm.)	Σ (mm.)
June 22	20·2°	1·216	0·945	2·161	20·2°	1·252	0·929	2·181
	1787 MV	2·254	0·386	2·640	1797 MV	2·237	0·407	2·644
	4088	2·802	0·096	2·898	4103	2·815	0·073	2·888
	6548				6548			
June 23	20·2°	0·149	2·325	2·176	20·2°	0·111	2·304	2·193
	1792 MV	1·905	0·771	2·676	1804 MV	1·873	0·785	2·658
	4116	1·340	1·487	2·827	4132	1·394	1·456	2·850
	6516	1·049	0·603	1·652	6581	1·014	0·637	1·651
	7937				7949			

measurements upon the silver bar as well as upon all those following it were carried out in the second oven tube only.

Tables IV*a* and IV*b* contain the individual measurements.

TABLE IV *b*.

Silver Bar.

t	Σ' (mm.)		λ_s (mm.)	
	June 22.	June 23.	Observed.	Calculated.
0°			0	0
250	2·352	2·360	2·356	2·356
500	2·640	2·640	4·996	5·002
750	2·970	2·921	7·941	7·938
875	----	1·649	9·590	9·515

The first day's heating produced a permanent increase in the length amounting to $0{\cdot}027^{mm}$, the second $0{\cdot}039^{mm}$. The length at the close was $484{\cdot}1^{mm}$ at 0°. The formulæ are

$$\lambda_s = 8{\cdot}844t + 0{\cdot}00232t^2(\mu)$$
$$\lambda = \{18270t + 4{\cdot}793t^2\}10^{-5}$$

5. *Nickel.*

The nickel bar (6^{mm} in thickness) was at first ruled with five scale divisions on each end like the others and the observations only extended to 750°. In spite of the fact that the metal tarnished when heated, the divisions remained clear and sharp throughout until, at the close of the third series of observations, the temperature was carried up to 1000°. At this temperature not only did the divisions disappear but the surface and the contour lines of the bar could scarcely be distinguished from the oven background.

To remedy this a small thin platinum plate was prepared, some 5×5^{mm} in size and $0{\cdot}5^{mm}$ thick and shoved into carefully filed dove-tail grooves in the bar so as to sit tightly in place with its polished surface in exactly the same position which the lost marks upon the nickel had occupied. Upon this platinum surface which of course also lay in the axis of the bar, new divisions were ruled and used in the two subsequent series of observations. If we assume from the ratio of the lengths that 1 per cent of the expansion is due to the platinum, the result will be influenced only $0{\cdot}01(5{\cdot}78-3{\cdot}57)=0{\cdot}02^{mm}$ at 750°.

The length of the bar during the first observations was $482{\cdot}6^{mm}$ at 0°; after the insertion of the platinum plates the new sets of divisions proved to be $0{\cdot}2^{mm}$ further apart. The last observations are corrected for this increase in the length of the bar.

The nickel differed from the metals already described in that the permanent changes in the total length were in the opposite direction; the bar after cooling was always shorter than before —after the first two series, 0·024^{mm} and 0·018^{mm}, and after the last two, 0·016^{mm} and 0·035^{mm}, respectively.

The observations (Table V*a* and V*b*) can be represented by a quadratic formula only above 375°. The measured expan-

TABLE V*a*.
Nickel Bar.

	t	M (mm.)	M′ (mm.)	Σ (mm.)	t	M (mm.)	M′ (mm.)	Σ (mm.)
June 30	19·1°				19·0°			
	1811 MV	1·354	0·227	1·581	1815 MV	1·377	0·218	1·595
	4072	1·548	0·407	1·955	4081	1·542	0·415	1·957
	6551	1·257	0·882	2·139	6561	1·261	0·865	2·126
July 2	19·8°				19·8°			
	1803 MV	1·102	0·469	1·571	1815 MV	1·142	0·463	1·605
	2914	0·953	0·038	0·991	2927	0·941	0·029	0·970
	4066	0·651	0·330	0·981	4075	0·639	0·343	0·982
	6551	1·286	0·863	2·149	6563	1·306	0·848	2·154
July 4	20·2°				20·2°			
	1793 MV	0·937	0·673	1·609	1799 MV	0·953	0·648	1·601
	4078	1·766	0·202	1·968	4083	1·753	0·218	1·971
	6552	1·314	0·822	2·136	6560	1·325	0·814	2·139
Sept. 18	17·7°				17·8°			
	6541 MV	5·674	−0·005	5·669	6537 MV	5·671	−0·013	5·658
	9356	2·591	−0·205	2·386	9358	2·612	−0·222	2·390
Sept. 19	18·4°				18·4°			
	6578 MV	5·942	−0·271	5·671	6578 MV	5·939	−0·275	5·664
	9332	2·495	−0·158	2·337	9330	2·505	−0·179	2·326

TABLE V*b*.
Nickel Bar.

t	Σ′ (mm.) June 30.	July 2.	July 4.	Sept. 18.	Sept. 19.	λ_2 (mm.) Observed.	Calculated.
0°						0	0
250	1·670	0·975	1·708			1·685	(1·724)
375	1·957	0·990	1·953	5·770	5·748	2·660	2·661
500						3·643	3·648
750	2·155	2·168	2·164			5·782	5·772
1000	----	----	----	2·313	2·313	8·095	8·096

sion at 250° falls out of the curve entirely as may be seen at once by calculating $\frac{\lambda}{t}$. This exceptional behavior was not unexpected, however, on account of the change which takes place in nickel in the neighborhood of 300° where its magnetic properties disappear.

Below this temperature therefore the formulæ

$$\lambda_s = 6{\cdot}496t + 0{\cdot}00160t^2(\mu)$$
$$\lambda = \{13460t + 3{\cdot}315t^2\}10^{-9}$$

do not apply: the term in the first power is there smaller while the quadratic term increases.

6. *Constantan (60 Cu, 40 Ni).*

The electrical conductivity as well as the thermo-electrical properties of constantan are peculiar, but in its expansion it differs little from other alloys. It has a coefficient corresponding to about the mean of those of the component metals.

The bar used was 6^{mm} in diameter and the scale divisions drawn upon the metal itself as with the earlier metals described, in consequence of which the marks grew fainter as the oxidation increased although the observations were only extended to 500°. The permanent changes in the total length reached a maximum value of about $0{\cdot}01^{mm}$. The length at 0° was $483{\cdot}0^{mm}$.

The results (Tables VI*a* and VI*b*) may be expressed by the following formulæ:

$$\lambda_s = 7{\cdot}156t + 0{\cdot}00194t^2(\mu)$$
$$\lambda = \{14810t + 4{\cdot}024t^2\}10^{-9}$$

TABLE VI*a*.

Constantan Bar.

	t	M (mm)	M′ (mm.)	Σ (mm.)	*t*	M (mm.)	M′ (mm.)	Σ (mm.)
Sept. 24	17·9°				17·9°			
	1818 MV	1·854	−0·023	1·831	1821 MV	1·877	−0·057	1·820
	4036	2·215	−0·125	2·090	4036	2·187	−0·100	2·087
Sept. 25	17·9°				17·9°			
	1815 MV	1·723	0·090	1·818	1820 MV	1·750	0·052	1·802
	2917	1·374	−0·348	1·026	2927	1·366	−0·335	1·031
	4007	0·972	0·056	1·028	4011	0·956	0·063	1·019

TABLE VI *b*.

Constantan Bar.

t	Σ' (mm.) Sept. 24.	Σ' (mm.) Sept. 25.	λ_s (mm.) Observed.	λ_s (mm.) Calculated.
0°			0	0
250	1·916	1·903	1·910	1·910
375	2·159	1·040	2·950	2·956
500		1·106	4·063	4·063

7. *Wrought Iron.*

The bar of wrought iron as well as the steel bar described below were provided, before beginning the observations, with small platinum plates carrying the scale divisions, in the same way as the nickel bar above. One of the scale intervals at one end of the iron bar increased in length some 0·03^{mm} in consequence of the heating, nearly all of it occurring during the first day. None of the other divisions showed any noticeable change. The observations were not continued above 750° in order to avoid the permanent changes in the nature of metal such as occur in steel especially after long continued heating to high temperatures. The magnetic metals are known to

TABLE VII *a*.

Iron Bar.

	t	M (mm.)	M′ (mm.)	Σ (mm.)	t	M (mm.)	M′ (mm.)	Σ (mm.)
July 19	22·0°				22·0°			
	1841 MV	1·267	0·227	1·494	1847 MV	1·277	0·211	1·488
	4069	1·872	−0·030	1·842	4068	1·857	−0·024	1·833
	6564	1·823	0·170	1·993	6551	1·854	0·129	1·983
July 21	22·7°				22·7°			
	1816 MV	1·259	0·207	1·466	1823 MV	1·294	0·166	1·460
	2927	1·266	−0·364	0·902	2930	1·247	−0·349	0·898
	4077	0·987	−0·038	0·959	4077	0·966	−0·014	0·952
	6572	1·951	0·039	1·990	6567	2·004	−0·027	1·977
July 25	22·6°				22·6°			
	1803 MV	1·334	0·129	1·463	1807 MV	1·376	0·093	1·469
	4066	2·348	−0·473	1·875	4065	2·305	−0·453	1·852
	5248	0·963	0·016	0·979	5244	0·956	0·036	0·992
	6568	1·188	−0·188	1·000	6569	1·213	−0·211	1·002

TABLE VII*b*.

Iron Bar.

t	Σ' (mm.) July 19.	July 21.	July 25.	λ_s (mm.) Observed.	Calculated.
0°	1·570	1·565	1·577	0	0
250		0·905		1·571	1·571
375	1·890	0·979	1·889	2·476	2·475
500				3·459	3·459
625	1·967	1·960	0·990	4·449	(4·522)
750			0·964	5·419	(5·664)

show an independent increase in length upon being magnetized, which must at least be considered here. We should expect with iron and steel in the weak field of the heating coil (at 250° H=30, at 500° H=42 at the middle point of the bar) a lengthening of the order of magnitude 5×10^{-6} of the length,* which for these measurements would be entirely negligible.

The iron bar (thickness 6^{mm}) was $482{\cdot}7^{mm}$ long at 0° and showed a permanent change after the three heatings of 0·01, −0·025 and $-0{\cdot}025^{mm}$ respectively.

Tables VII*a* and VII*b* contain the measurements, which are very well represented by a parabola up to 500°.

The equations are

$$\lambda_s = 5{\cdot}650t + 0{\cdot}00254t^2(\mu)$$
$$\lambda = \{11705t + 5{\cdot}254t^2\}10^{-9}$$

Above 500° the expansion increases less rapidly.

8. *Steel.*

In order that the difference in the nature of the material be as large as possible, a bar of steel with a high percentage of carbon was chosen.

The original length of the bar (thickness 6^{mm}) at 0° was $482{\cdot}8^{mm}$ and decreased $0{\cdot}10^{mm}$ during the first heating, but the subsequent changes did not exceed $0{\cdot}04^{mm}$.

The observations are contained in the Tables VIII*a* and VIII*b*.

If the curves

$$\lambda_s = 4{\cdot}428t + 0{\cdot}00402t^2(\mu)$$
$$\lambda = \{9173t + 8{\cdot}336t^2\}10^{-9}$$

be laid out through the points 250° and 500° the observed value at 375° falls wide. The expansion of steel seems to be somewhat irregular even below 500°.

* Ewing, Induction in Iron, § 143.

TABLE VIII *a*.
Steel Bar.

	t	M (mm.)	M′ (mm.)	Σ (mm.)	t	M (mm.)	M′ (mm.)	Σ (mm.)
July 6	19·7°				19·7°			
	1801 MV	0·850	0·436	1·286	1809 MV	0·854	0·441	1·295
	4080	1·453	0·400	1·853	4088	1·463	0·397	1·860
	6535	1·431	0·140	1·571	6540	1·435	0·145	1·580
July 16	20·5°				20·5°			
	1824 MV	0·981	0·319	1·300	1828 MV	1·007	0·298	1·305
	2909	0·923	−0·047	0·876	2913	0·914	−0·041	0·873
	4150	0·628	0·394	1·022	4141	0·609	0·399	1·008
July 17	22·2°				22·2°			
	1813 MV	1·080	0·204	1·284	1817 MV	1·108	0·173	1·281
	4062	1·613	0·229	1·842	4060	1·595	0·236	1·831
	5274	0·555	0·445	1·000	5269	0·550	0·443	0·993
	6556	0·611	0·090	0·701		0·640	0·076	0·716

TABLE VIII *b*.

t	Σ′ (mm.) July 6.	July 16.	July 17.	λ_n (mm.) Observed.	Calculated.
0°		1·360	1·357	0	0
250	1·361	0·896	1·871	1·359	(1·359)
375	1·866	0·953		2·255	(2·227)
500			0·979	3·221	(3·221)
625	1·582		0·704	4·200	(4·341)
750				4·904	(5·586)

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Sulphur Hexafluoride, Thionyl Fluoride, and Sulphuryl Fluoride.*—Moissan and Lebeau have recently described several new gases containing sulphur and fluorine. Sulphur hexafluoride, SF_6, is produced when gaseous fluorine is brought into contact with sulphur. The sulphur immediately takes fire and burns with a bright flame. The gas thus produced is very remarkable for its great stability, as it has neither taste nor odor, and is not decomposed by water nor even by caustic potash solution. Although very rich in fluorine, the colorless gas, in its inertness, resembles nitrogen rather than the chlorides of sulphur. It is slightly soluble in water. At $-55°$ it solidifies to a white crystalline mass which melts and then boils at a temperature a little above its point of solidification. It is not attacked by fused lead chromate, fused caustic potash nor by copper oxide at a low red heat. Sodium may be fused in contact with the gas without action taking place, but when the sodium is brought to the boiling point combination takes place with incandescence.

Thionyl fluoride, SOF_2, is prepared by the action of fluorine upon thionyl chloride, and also by the reaction of arsenious fluoride with thionyl chloride. It is a colorless gas which fumes slightly in moist air, and which has a disagreeable, suffocating odor. It is decomposed by water at the ordinary temperature, with the formation of sulphur dioxide and hydrofluoric acid. In general it is much more active than sulphur hexafluoride.

Sulphuryl fluoride, SO_2F_2, is most conveniently prepared by the combination of fluorine and sulphur dioxide. These gases burn when brought together if the combustion is started by means of a hot platinum wire. This is a remarkably stable gas, but it is not quite as inactive as SF_6. It is colorless and odorless, does not act upon water even at 150°, but is decomposed by aqueous or alcoholic caustic potash with the formation of potassium fluoride and sulphate. It becomes liquid at $-52°$, solidifies when exposed to the temperature of liquid oxygen, and melts at $-120°$. It reacts with many substances at high temperatures.—*C. R.*, cxxx, 865, 1436; cxxii, 374. H. L. W.

2. *The Molecular Weight of Ozone.*—The molecule O_3 is generally admitted to belong to ozone, but the facts upon which this assumption is based possibly leave some room for doubt in regard to the matter. A. Ladenburg, therefore, has devised a new method for determining the specific gravity of this gas. He weighed a glass globe filled with dry oxygen, then filled it with some of the same sample of oxygen after it had been ozonized and weighed again at the same temperature and pressure. After this he absorbed the ozone by means of oil of turpentine, and

thus determined the volume which it had occupied. These data sufficed for ascertaining the weight of ozone compared with that of oxygen, and several determinations made in this way served to confirm the accepted view in regard to the molecular weight of this substance.—*Berichte*, xxxiv, 631. H. L. W.

3. *The Preparation of Chlorine from Sodium Chlorate.*—Since sodium chlorate is now produced on the large scale as a very pure product, and since this salt is extremely soluble in water, C. Graebe recommends its use for preparing chlorine gas in the laboratory by allowing the concentrated solution to flow slowly into boiling dilute hydrochloric acid. This is a modification of the method recommended by Gooch and Kreider, in which warm hydrochloric acid is allowed to act upon lumps of previously fused potassium chlorate in a Kipp generator.

Graebe finds that his process yields chlorine containing only about 5 per cent of chlorine dioxide. For small quantities of the gas he uses hydrochloric acid of 1·10 specific gravity, while for larger quantities he prefers 1·12 acid. The acid can be used until the strength has fallen to 5 or 6 per cent. With 100^{cc} of 1·10 acid about 16 g. of chlorine can be obtained, and with the stronger acid, about 20 g. 1 g. of sodium chlorate yields about 2 g. of chlorine. The solution of this salt is made by dissolving 100 g. of it in 120 to 150^{cc} of hot water and afterwards diluting to 200^{cc}, so that 1^{cc} corresponds to a gram of chlorine. A special cylindrical, graduated dropping funnel is recommended, and the end of its stem should dip under the surface of the acid and be drawn out and bent upward.—*Berichte*, xxxiv, 645. H. L. W.

4. *New Alkaloids in Tobacco.*—Heretofore only a single alkaloid, nicotine, has been found in tobacco, although most other alkaloid-yielding plants have been found to contain a number of these bodies. Pictet and Rotschy have now shown that tobacco contains several alkaloids in addition to nicotine, and, consequently, that this plant is not an exception to the general rule. These chemists used the aqueous extract, concentrated in a vacuum, of 100 kg. of dried Kentucky tobacco. The liquid amounted to about 11·4 kg. and contained about 10 per cent of nicotine. After adding caustic soda and distilling with steam, both the residual liquid and the crude volatile alkaloid were examined for new bases. From the former, by extraction with ether and subsequent purification, two alkaloids were obtained. One of them, a liquid boiling at 266–268°, to which the name *Nicoteïne* is given, gave analytical results corresponding to the formula $C_{10}H_{12}N_2$. The other, called *Nicotelline*, was obtained as a solid from a higher-boiling fraction. This melts at 147–148°, and apparently has the formula $C_{10}H_8N_2$. By a somewhat intricate process a third alkaloid, called *Nicotimine*, was extracted from the large mass of crude nicotine. This base boils at about 250°, which is several degrees higher than the boiling-point of nicotine. It shows great similarity to the latter alkaloid and is believed to be isomeric with it.

The following formulæ are given for the alkaloids of tobacco:

Nicotine	$C_{10}H_{14}N_2$
Nicotimine	$C_{10}H_{14}N_2$
Nicoteïne	$C_{10}H_{12}N_2$
Nicotelline	$C_{10}H_8N_2$

The following table is given as a rough estimate of the quantities of these alkaloids in 10 kg. of the concentrated tobacco extract:

Nicotine	1000 g.
Nicoteïne	20 g.
Nicotimine	5 g.
Nicotelline	1 g.

Only one of the new alkaloids, nicoteïne, has been tested in regard to its physiological action. This appears to be even more poisonous than nicotine itself.—*Berichte*, xxxiv, 696. H. L. W.

5. *The Hydrate of Sulphuryl Chloride.*—Baeyer and Villiger have found that when sulphuryl chloride, SO_2Cl_2, is poured into ice-cold water a beautifully crystallized hydrate is formed, which, curiously enough, has not been previously noticed. The substance has the appearance of camphor, is only very slightly soluble in water at 0°, and in small quantities remains unchanged for hours under ice-cold water. When the hydrate is slightly warmed with water an oil separates which appears to be unchanged sulphuryl chloride, for the hydrate is formed again upon cooling. Analysis showed that the compound probably has the composition represented by the formula $SO_2Cl_2.15H_2O$.—*Berichte*, xxxiv, 736. H. L. W.

6. *The Action of Hydrogen Peroxide upon Silver Oxide.*—According to Thenard these two substances reduce each other with the formation of oxygen, water and metallic silver. Berthelot advanced the view, however, that in this reaction only the extra oxygen of the hydrogen peroxide is evolved, while the oxygen given up by a part of the silver is retained by another part of it in the form of a higher oxide of that metal. Baeyer and Villiger have now shown clearly that Thenard's view is entirely correct, and that Berthelot was wrong in regard to this matter. Since finely divided metallic silver exerts a powerful catalytic action upon hydrogen peroxide, it is difficult to reduce silver oxide completely by means of a solution of this substance. By using about five times the theoretical quantity of hydrogen peroxide, however, and adding it slowly with thorough agitation, Baeyer and Villiger have obtained a practically complete reaction, and have found no evidence of the formation of a higher oxide of silver. They have shown also that more oxygen is always evolved when hydrogen peroxide acts upon silver oxide than when it acts upon a simple catalytic substance like finely divided platinum or silver, and that, under the proper conditions, the volume of oxygen given off corresponds to Thenard's theory. —*Berichte*, xxxiv, 749. H. L. W.

7. *Action of Alcohol on Metals with which it comes in Contact.*—After allowing pure 95 per cent alcohol to act upon several metals for a period of six months in corked flasks, Dr. MALMÉJAC has found that a considerable amount of action took place in several cases. With copper, there was no turbidity, and no residue was left upon evaporating some of the alcohol. With tin there was a decided turbidity, but the filtered alcohol gave a hardly observable residue. In the cases of zinc, lead, iron, and galvanized iron, there were considerable amounts of turbidity, and the filtered alcohol in each case left a decided residue, which was rather large in the case of lead. These experiments have an important bearing upon the choice of vessels used for the storage of alcohol.—*Chem. News*, lxxxiii, 115. H. L. W.

8. *On the Excitation and Measure of Sine Currents.*—One of the greatest needs in the subject of electrical measurements is an apparatus which will produce sine currents. The theory of periodic currents presupposes an accurate sinusoidal variation; but the instruments which are used to test the theory give in no case hitherto true sine waves. MAX WIEN describes in a leading article a method which seems to be a valuable one. The sine waves are produced by the revolution of a brass wheel in the periphery of which are numerous insertions of pieces of soft iron. This wheel is the analogue of the perforated disc of the syren in the subject of acoustics. The wheel revolves between stationary poles of an electromagnet, upon which are induction coils, in which the sinusoidal variations are produced. By means of a condenser the circuit is tuned to resonance, and accurate sine waves are produced, since by the tuning the harmonics are rendered weak, and only the fundamental tone of the circuit is preserved.—*Ann. der Physik.*, No. 3, 1901, pp. 427–458. J. T.

9. *Metallic Reflection of Electrical Waves.*—Righi has described an experiment in which he claimed to have observed elliptical polarization of electrical waves at metallic surfaces. KARL F. LINDMAN quotes the theoretical conclusion of Poincaré and of Drude, to prove the impossibility of this for waves certainly 10^{cm} in length. He concludes that this elliptical polarization does not exist, and he finds that the electrical waves are linear polarized. The results of Righi are attributed to some unexplained disturbance.—*Ann. der Physik.*, No. 3, 1901, pp. 617–637. J. T.

10. *The Light Transparency of Hydrogen.*—V. SCHUMANN, the author of the remarkable paper on very short wave-lengths of light in a vacuum, has shown that a layer of hydrogen gas is very transparent to light and allows the shortest waves to pass through it unabsorbed. He found, however, strange inconsistencies in his work, and in the present paper explains their cause. In the earlier experiments the gas was led into the apparatus through a rubber tube, and the use of this tube was found to lessen the transparency of the hydrogen. When it was dispensed with and great care was taken in preserving the hydrogen from

contamination, it was found that hydrogen transmits the shortest waves as well as a vacuum.—*Ann. der Physik*, No. 3, 1901, pp. 642–645. J. T.

11. *Measurement of the Röntgen Rays by means of Selenium.*—F. HIMSTEDT, in an investigation on the X-rays and the Becquerel rays, shows that these rays alter the resistance of selenium, and he hopes to devise a plan for the qualitative measurement of these rays.—*Ann. der Physik*, No. 3, 1901, pp. 531–536. J. T.

12. *The Effect of the Röntgen Rays and the Becquerel Rays on the Eye.*—Giesel has shown that a preparation of radium laid upon the eyelid gives a sensation as if the entire eye was filled with light. F. HIMSTEDT and W. A. NAGEL have made a careful examination of this phenomenon, and also of the effect of the X-rays on the eye. They show that a fluorescence is excited in the organs of the eye which produces the sensation of light. Their work confirms the investigations of previous observers and somewhat extends them.—*Ann. der Physik*, No. 3, pp. 537–552, 1901. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *The Eocene and Lower Oligocene Coral Faunas of the United States*, with descriptions of a few doubtfully Cretaceous species; by T. WAYLAND VAUGHAN. Monograph, vol. xxxix, pp. 263, 24 pl. U. S. Geological Survey. Washington, 1900.—Upon taking up the study of the Tertiary corals, Mr. Vaughan set for himself the task of defining every species presenting good and identifiable figures, showing their stratigraphic range and geographic distribution; then, secondly, he sought to determine from the study of the corals, the bathymetric conditions under which they lived and were buried; and thirdly, to trace, so far as practicable, the affinities of the forms met with. He brought to the solution fine equipment and excellent collections, and has performed his task well. The descriptions and delineations of species appear to be all that could be wished for. The questions: what is a species? and how to classify corals? have been conscientiously met and judiciously handled, but the author, like other workers in this field, leaves the burden of proposing something better than the current system to those who will follow.

The study of the bathymetric distribution of the species on a basis of known depths at which corresponding genera are now living leads to the conclusion that the faunas of the Eocene and Oligocene under investigation lived at only moderate depth, not over 100 fathoms, and 18 out of 24 genera now live in water less than 50 fathoms deep. The author gives valuable statistics regarding the bathymetric values of the faunas of the several formations studied. An excellent account of the morphology of the Madreporarian coral skeleton is given, which will be helpful to students.

The volume is a distinct contribution to the systematic knowledge of Tertiary corals. W.

2. *On the presence of a Limestone Conglomerate in the Lead region of St. Francis Co., Missouri;* by FRANK L. NASON. (Communicated.)—For the past two months, the writer has been engaged in geological work in the disseminated lead fields in St. Francis County, Missouri. During the progress of the work a heavy bed (or beds) of limestone conglomerate has been discovered separating the St. Joseph, or Bonne Terre, limestones from the formation known as the Potosi. The interstitial filling of this conglomerate is a pure coarsely crystalline limestone, in sharp distinction to the magnesian limestone or dolomite which forms the pebbles. The interstitial part is filled with fragments of trilobites, brachiopods and possibly crinoid stems, all undetermined at present. I wish to announce now this discovery, which is of great importance geologically and promises to be of even greater importance economically in relation to the disseminated lead deposits of this section of Missouri. In a few weeks I hope to publish a geological section showing the relative position of the conglomerate with reference to the St. Joseph limestones and the Potosi.

3. *New Species of Cambrian fossils from Cape Breton;* by G. F. MATTHEW, Nat. Hist. Society of New Brunswick Bulletin, vol. iv, p. 219, with a plate. (Abstract by the author.)—In this paper on fossils from the Upper Cambrian of Cape Breton, nine new species and forms are described. These are referred to the several zones of Parabolina, Peltura and Dictyonema. The internal features of the valves of several of the Brachiopods are described and figured. An enlarged figure shows the complicated structure of the group of central muscles in Lingulella. A new Schizambon described is a minute orbicular form from the Dictyonema zone. This and a new Acrotreta have been found also in the Cambrian Basin at St. John, N. B., Canada.

The trilobites are of three genera, Parabolina, Sphærophthalmus and Agnostus. The first genus is represented by a species with a strongly arched front to the cephalic shield, but in other respects strongly resembles the European forms referred to this genus. The Agnostus is a fine example of *A. trisectus* of Salter, but differing in the markings of the surface of the shield and in having a tubercle at the back of the rhachis of the pygidium.

4. *Geological Survey of Western Australia.*—The Annual Report for the year 1899 has been recently issued. It contains an account of the Greenbushes tin fields, by the Government geologist, A. GIBB MAITLAND, with a detailed geological map; also of various gold fields, chiefly in the Coolgardie district, accompanied by geological maps. The mineralogist, Mr. Edward S. Simpson, gives results of assays of some twelve samples of native gold, in part nuggets, but chiefly from quartz reefs. Most of them show the presence of a considerable percentage of silver, from 3·5 to 10·5 p. c. The lowest specific gravity observed (14·66) is that of the "Bobby Dazzler" nugget, which yielded

gold 76·81, silver 23·04, copper and iron 0·15. The purest specimen was a sample of sponge gold from Boulder, East Coolgardie; this yielded gold 99·91, silver 0·09.

Some further information is given in regard to the problematical tantalo-niobate from the tin-bearing gravels at Greenbushes, called by Goyder stibiotantalite. (Dana Min., App. I, p. 64.) This allows of a somewhat fuller description of the mineral than has been given before, and the hope is held out that material pure enough for complete analysis may be separated. Associated with this mineral, grains of metallic tin were identified. Cobaltiferous asbolite has been found at Norseman and Kanowna; it is associated with gold, at the latter place being often studded with minute crystals.

5. *Geology of Texas.*—The Transactions of the Texas Academy of Science for 1899, volume iii, contains a summary, prepared by Prof. F. W. Simonds, of publications on the Geology of Texas up to the end of 1896; a brief summary of the contents of each paper is given.

6. *Concretions from the Champlain Clays of the Connecticut Valley;* by J. M. Arms Sheldon. With one hundred and sixty illustrations by Katharine Peirson Ramsay, L. R. Martin, and F. S. and M. E. Allen. Pp. 45, pl. I–XIV, 4to. Boston, 1900.—The author has given in this volume an interesting and exhaustive account of the concretions found in the Connecticut Valley clays. They were collected at different points between Dummerston, Vermont, and Deerfield, Massachusetts. The method of occurrence is fully described and the origin, chemical composition, and other points are discussed with all necessary detail. A considerable series of analyses shows a substantially uniform composition, differing somewhat for samples from different layers. The memoir closes with a full bibliography; it is illustrated by a series of fourteen admirable heliotype plates, which leave nothing to be desired in the way of presenting the varieties of form and structure.

7. *Study of the Gabbroid Rocks of Minnesota.*—The elaborate memoir by Alexander N. Winchell, containing a mineralogical and petrographic study of the gabbroid rocks of Minnesota, and more particularly of the plagioclastyes, noticed on page 89 of this volume of the Journal and republished in the American Geologist (volume xxvi), has been recently issued in pamphlet form.

8. *On the Flow of Marble under Pressure.*—The full memoir by Adams and Nicolson on this subject, of which an abstract was given in the number of this Journal for November last (p. 401), has recently been issued (pp. 363–401 of vol. cxcv, Pt. A of the Philosophical Transactions of Royal Society of London). The plates and other illustrations accompanying it add much to the clearness of the description and increase the general interest of the subject.

9. *The Flora of Cheshire* (400 pp., 8vo, Longmans, Green & Co.) is a carefully prepared work compiled by Mr. SPENCER MOORE from the manuscripts of the late Lord de Tabley. The extraordinary versatility of the author is well portrayed in an introductory biographical sketch. Chiefly known as a poet, dramatist, and novelist, Lord de Tabley found time to write seriously upon the federal coinage of Ancient Greece, produce a noteworthy work upon bookplates, and prepare the botanical manuscripts of remarkable detail from which the present posthumous work has been compiled. The Flora contains neither technical descriptions nor keys. There is a careful physico-botanical account of the different sections of the region covered, a list of and some notes upon the persons concerned in the past with Cheshire botany, an extensive list of works consulted, and finally the body of the catalogue, which is restricted to the spermatophytes, pteridophytes, and *Characeæ*. In looking over its pages one is impressed chiefly by the extraordinary minuteness and detail with which habitats and stations have been recorded. A single instance chosen at random will suffice to show the nature of the work in this regard. One of the meadow grasses is said to be "Plentiful in one spot on the shore of the Dee near Parkgate (destroyed in this locality, 1854); amongst shingle and at the base of the wall in the first field enclosure north of Parkgate; in the sandy tract commencing under the garden wall of the house at Old Quay a mile south of Parkgate; and seen now and again between the colliery and the gravel pit on that side of Benton Point, 1873." While all this may be of some interest to the local observer for whom, of course, it was primarily intended —if indeed the author ever expected that it would see light in print—yet, considered as a scientific publication, it runs far into the realm of the casual, if not the trivial. There is, furthermore, no synonymy, little bibliography except in relation to ranges, and finally a curious lack of those comparative or descriptive notes upon local varieties, in fact, of observations upon the plants themselves aside from their abundance and stations. In all these respects this stout volume is almost as barren as a mere list would be. B. L. R.

10. *A preliminary list of the Spermatophyta of North Dakota;* by HENRY L. BOLLEY and LAWRENCE R. WALDRON (Bulletin No. 46 of the North Dakota Experiment Station).—No catalogue of the plants of North Dakota has heretofore been published and the present list is thus a piece of pioneering work. As such it will, notwithstanding its manifest and frankly confessed incompleteness, prove useful. It is furthermore of no small interest as showing for the first time in concise form the general nature of the vegetation in what is, as to its floral conditions, probably the most uniform of our larger states. A striking characteristic noticeable in the vegetation, as shown in this catalogue, is that nearly all of the species are those of wide range, endemic or truly local plants being almost unknown in the state. Another

feature of the flora which is noteworthy is the extreme paucity of species in certain usually well represented families; thus but 41 *Cyperaceæ* are recorded. This, it is true, may well be due largely to the difficulty of the group and the fact that many species present in the flora have yet to be discriminated and recorded. The same explanation, however, can hardly apply to the *Ericaceæ*, of which but one species, or to the ferns, of which only two species, *Cystopteris fragilis* and *Onoclea Struthiopteris*, are recorded for any part of the state. B. L. R.

III. Miscellaneous Scientific Intelligence.

1. *The new Star in Perseus.*—As a culminating result of the vigilance with which Dr. Thomas D. Anderson of Edinburgh, Scotland, has watched the northern heavens and which has furnished us with some two dozen new variable stars in the past few years, a new star in Perseus was discovered by him on February 21 at 14 hours 40 min. Greenwich mean time. It was then a little brighter than a third magnitude star and shone with a bluish-white light. The northern sky is now so extensively patrolled by photography that for the first time in the history of sudden apparitions of new stars we are able to say almost definitely when the outburst took place. A photograph taken at Harvard on February 19 shows no trace of the star, though stars to the eleventh magnitude are impressed, and a valuable plate secured by A. Stanley Williams, of Hove, Sussex, England, 28 hours before the discovery by Dr. Anderson, makes it certain that the new star must have then been fainter than a twelfth magnitude star. We are, therefore, able to time the occurrence within 14 hours.

The star continued to increase in brilliancy until February 23, when it was estimated at Harvard as of the magnitude 0·0, that is about a quarter magnitude, or about 25 per cent brighter than any star in the northern hemisphere, and only falling below Sirius and Canopus in the southern sky. This brilliancy has only been surpassed by temporary stars twice in historic records, once in 1572 and again in 1604, the two new stars described by Tycho and Kepler. On February 24 when the *nova* was first seen at the Yale Observatory, in broad daylight, it had already fallen to equality with Capella and diminished during the day fully half a magnitude. Since then the decline has been slow and steady with occasional fluctuations, and about April 1 it was of the fifth magnitude or 100 times fainter than at its maximum; and the color had gradually changed to an orange hue.

The most interesting and valuable features of the apparition will doubtless be found in the spectroscopic results. At present all the data have of course not been collated and discussed, but it seems certain that an earlier stage of development has been observed than on any previous new star. The first observations at Harvard, on February 22, show a spectrum quite unlike that of

other new stars, being continuous with a number of dark lines, and a few inconspicuous bright lines. By February 24, however, the star seems to have attained the stage observed in the new star in Auriga in 1892, as there appear two superposed and slightly separated spectra, one of dark and one of bright lines, either showing the presence of two bodies with enormous relative velocities or, more likely, some remarkable physical conditions in one body alone. The interpretation of the totality of the phenomena presented by this star will doubtless prove very valuable for our knowledge of the constitution and formation of the stellar universe. W. L. E.

2. *National Academy of Sciences.*—The annual meeting of the National Academy was held in Washington, April 16–18th. The list of papers presented is given below. Professor Alexander Agassiz was elected President in place of Dr. Wolcott Gibbs, who resigned in April, 1900. Dr. Arnold Hague was elected Home Secretary and Professor Ira Remsen Foreign Secretary. The following gentlemen were made members of the Academy: Dr. George F. Becker of Washington, Prof. J. McK. Cattell and T. M. Prudden of New York, Prof. E. H. Moore of Chicago and Prof. E. F. Nichols of Ithaca. The titles of papers presented are as follows:

HENRY L. ABBOT: The climatology of the Isthmus of Panama.

R. S. WOODWARD: The effects of secular cooling and meteoric dust on the length of the terrestrial day.

ALPHEUS HYATT: The use of formulæ in demonstrating the relations of the life history of an individual to the evolution of its group.

E. B. WILSON: Artificial parthenogenesis and its relation to normal fertilization.

CARL BARUS: Simultaneous volumetric and electric graduation of the condensation tube.

W. O. ATWATER: Table of results of an experimental inquiry regarding the nutritive action of alcohol.

THEO. GILL: The significance of the dissimilar limbs of the Ornithopodous Dinosaurs.

J. W. POWELL: The place of Mind in Nature. The foundation of Mind.

ALEXANDER GRAHAM BELL: Conditions affecting the fertility of sheep and the sex of their offspring.

S. P. LANGLEY: The new spectrum.

3. *Report of the Secretary of the Smithsonian Institution for the year ending June 30th, 1900.* . Pp. 117, with 18 plates. Washington, 1900.—Prof. Langley's annual report gives a summary of the year's work by the Smithsonian Institution in its many directions of useful activity. The appendixes which follow the formal report contain more detailed statements in regard to some of the departments; as, the National Museum, the Zoological Garden, the International Exchange Service, and the Astrophysical Observatory, etc. The last report, by Mr. C. G. Abbot, Aid-in-charge, is especially interesting, since it details, with numerous illustrations, the work done by the Smithsonian party at the total eclipse of May, 1900. Mr. Abbot gives the following summary of the work of the Observatory:

"The operations of the Astrophysical Observatory during the past year have been distinguished, first, by the publication of the first volume of its Annals, in which the infra-red solar spectrum is the main topic; second, by progress in the preparation of a highly sensitive, steady, and magnetically shielded galvanometer; third, by observations of the total solar eclipse, in which excellent large-scale photographs of the corona were secured, the coronal extensions photographed to upward of three diameters from the moon's limb, the absence of intra-mercurial planets above the fourth magnitude made nearly certain and the presence of several such between the fifth and seventh magnitude rendered as probable as single photographs can do, and finally, in which the small but measurable intensity of the total radiations and the effectively low temperature of the inner corona were observed by the aid of the bolometer."

4. *Memorial of George Brown Goode.*—Report of the U. S. National Museum, Part II. Pp. 515, with 109 plates. Washington, 1901 (Annual Report of the Smithsonian Institution for the year ending June 30th, 1897).—This volume is devoted to a Memorial of Dr. George Brown Goode, giving also a selection of his papers on Museums and the History of Science in America. It opens with an account of the memorial exercises held to commemorate the life and services of Dr. Goode, on February 13th, 1897, with the addresses by Prof. Langley and others, delivered at that time. A memoir by Prof. Langley follows (pp. 41–61). The remainder of the volume is devoted to the re-publication of some of the papers by Dr. Goode. Dr. Goode's services to science were so important; his study of museums in general so thorough, and his labors in behalf of the one of which he was in charge so active and fruitful; his example as a man was so inspiring, that this volume must interest and benefit a large number of readers.

The opening paper discusses museum-history and gives an account of the older museums of the world. Another paper describes the origin and development of the U. S. National Museum; others are of general character and deal with museum administration and the progress of museums in the future. The discussions of the beginning of Natural History in America, and of American science in general, which are given in other papers, are most interesting, and bring together much material which it would be difficult to find in any other place. The volume is enriched by upwards of one hundred portraits of notable men, who, as scientists, explorers or statesmen, contributed to the advancement of science in this country.

5. *U. S. Coast and Geodetic Survey: Report of the Superintendent for the year from July 1st, 1898 to June 30th, 1899.* Pp. 964, 4to, with numerous plates and maps. Washington, 1900.—The annual volume of the U. S. Coast and Geodetic Survey contains the usual summary of the work, geodetic, hydrographic, magnetic, tidal, etc., which has been carried on in different parts of the country. This is followed by a series of

appendixes, one of which contains the statement of the progress made by the International Geodetic Association for the Measurement of the Earth. Another gives an exhaustive statement of work done in accurate leveling in the country with detailed observations. Still another describes the progress of the magnetic survey of North Carolina, recently inaugurated and conducted under the combined auspices of the Coast Survey and the State Geological Survey. This is accompanied by a declination map for the State. The concluding appendix, though brief, is particularly interesting as detailing the general magnetic work of the Survey, now under the charge of Dr. L. A. Bauer. Dr. Bauer has made a minute study of the earth's magnetism for a number of years, and the outlines given here of the investigations that it is proposed to carry on gives reason to hope that great progress may be made in this direction in the near future.

6. *La Navigation Sous-marine ;* par MAURICE GAGET. Pp. 472, 12mo. Paris, 1901 (Librairie Polytechnique, Ch. Béranger). —This compact volume contains a full summary of the subject of sub-marine navigation. It treats first of its history; then the theory involved is elaborated, and finally detailed descriptions are given of the various more or less successful modern attempts to solve the difficult problems involved. In this department the French have accomplished much and this work will be read with interest by all those whom the subject concerns.

7. *Geological Survey of Great Britain.*—Mr. J. J. H. Teall, President of the Royal Geological Society, has been chosen Director-General of the Geological Survey of the United Kingdom (see p. 252).

8. *Geological Survey of Canada.*—The Directorship of the Geological Survey of Canada, left vacant by the death of Dr. George M. Dawson, has been filled by the appointment of Dr. Robert Bell.

OBITUARY.

DR. HENRY A. ROWLAND, Professor of Physics at the Johns Hopkins University and one of the Associate Editors of this Journal, died at his home in Baltimore on Tuesday, April 16th, at the age of fifty-two years. A notice is deferred until a later number.

PROFESSOR GEORGE F. FITZGERALD, of the University of Dublin, died on February 21 at the age of forty-nine. He occupied a high place among English physicists and his scientific papers were of great value though not very numerous; the most important of them is a memoir (1878) on the "electro-magnetic theory of the reflexion and refraction of light." A movement for the founding of a memorial to Prof. Fitzgerald has been inaugurated; it is proposed to give it the form of an endowment of research in physical science by advanced students.

PROFESSOR CHRISTIAN F. LÜTKEN, the able Danish zoologist, died on February 6 at the age of sixty-three years.

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The European shipments to which attention was called in March, will be on sale about May 1st.

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RESTORATION OF

STYLONURUS LACOANUS, CLAYPOLE

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Yale University Museum, New Haven, Conn.

This species of Stylonurus ranks not only as the largest of the genus, but also as the most gigantic American arthropod yet discovered. The restoration was described by Dr. Beecher in a previous number of this Journal, where it is also figured. It is based on numerous remains of this and allied species, and so may be relied upon to portray with considerable accuracy this huge Merostome from the Catskill Group of New York and Pennsylvania.

Remains of the Stylonurus are scarce, and material sufficient to illustrate the genus is found in but few museums.

The animal is represented as lying on a slab measuring $5'-5'' \times 2'-11''$, which is filled by the restoration. With its great crawling legs extended to their farthest span this great arthropod would have measured about eight feet (242 c. m.) across, and nearly five feet (147 c. m.) in length.

We have acquired from Dr. Beecher the right to issue this model and offer it, packed and delivered to transportation company, for $25.

For information concerning Dr. Beecher's *models of Brachiopods* showing their embryology and the anatomy of their dorsal valves, and his *models of Trilobite* showing all appendages, also for Professor Marsh's restoration of *Dinoceras mirabile*, as well as for actual fossils and casts of fossils, or any other objects of Natural History, address

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